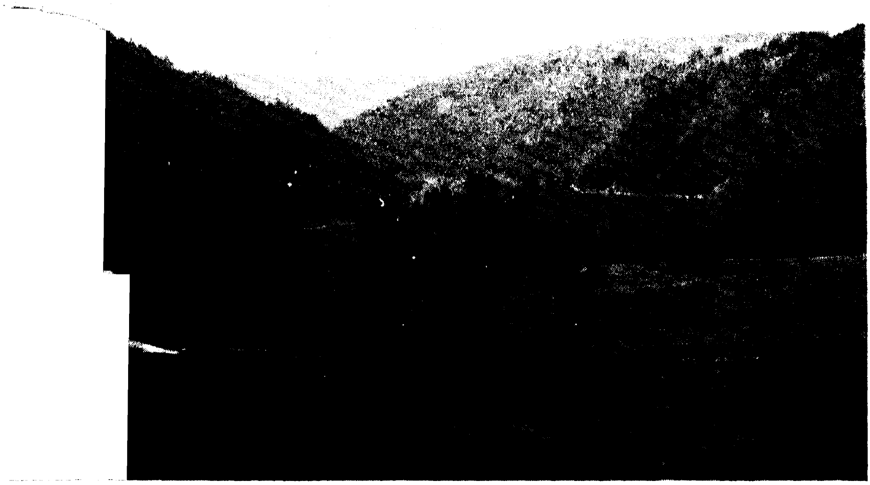

Fig. 1.

THE VALLEY OF THE ALB.

Geological and Petrographic Studies
IN
THE HERCYNIAN MOUNTAINS
AROUND TIEFENSTEIN
SOUTHERN BLACK FOREST, GERMANY

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1925

TO

MY FRIEND "T"

IN GRATEFUL MEMORY

OF HOW MUCH I OWE TO HIM

THIS LITTLE WORK

IS MOST AFFECTIONATELY DEDICATED

PREFACE

The field work which formed the basis of this paper was commenced in the Spring of 1922, and continued until the Winter of 1923, in conjunction with petrographical and chemical studies in the Mineralogical-Petrographical laboratories of the Federal Technical University and Cantonal University, Zurich, under the guidance and kind co-operation of Professor P. Niggli. Laboratory work was further continued until the Spring of 1924.

I beg to express here my sincere thanks and gratitude to Professor Dr. P. Niggli for his constant kind help and advice during the whole course of my studies. I would also thank his assistants (Dr. R. L. Parker, Dr. L. Weber, Dr. H. Suter and Dr. J. Jakob) for the friendly assistance that they have rendered me during the laboratory work. I am especially indebted to Dr. R. L. Parker for his kindly helping me in preparing the photographs.

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I. INTRODUCTION.

A. GEOGRAPHY.

THE area surrounding Tiefenstein surveyed by me, is situated in the south of the Black Forest in the Republic of Baden, subdivision Waldshut. It extends from the Rhine in the south to Vogelbach in the north. The boundary chosen follows a line running approximately N.—S. from Vogelbach, Niedermühle, Oberalpen, Birkingen, Dogern to the Rhine which marks there the political boundary between Switzerland and Germany. Leaving the Rhine at Hauenstein the boundary proceeds approximately S.–N. from Hauenstein, via Mühlebach, Sommerhalde, Haubach-Rotzel-Oberwihl road, Oberwihl, Rüsswihl, Görwihl to the Alb.

The total area studied by me comprises about 60 sq. k.m. Its greatest length from the Rhine to Niedermühle is about 10 k.m., and the greatest breadth from Oberwihl to Ellebühl in the valley of the Schurlebach is about 7 km. Included in the area are the villages of Albbruck, Schachen, Niederwihl, Rüsswihl, Görwihl, Wilfingen, Vogelbach, Unteralpen, Oberalpen, Tiefenstein, Buch, Etzwihl, Birndorf, Birkingen, Kiesenbach and a part of Dogern. It is watered by the Alb and many other rivulets all flowing to the Rhine in the south, and the Valley of the Alb is well known for its natural beauties all over the German-speaking part of Central Europe. (*Frontispiece.*)

Some of the Black Forest geologists believe that these rivers follow lines of N.–S. dislocation, but I was unable to find any trace of such. On the contrary, dyke-outcrops on the opposite sides of the valleys are in no way deflected from the normal position required by the strike direction. I consider the facts to be in agreement with the theory of H. Schardt, according to which the rivers are older than the mountains. During the orogenic movements the river beds maintained their direction, erosion keeping pace with the upheavals.

Dr. J. Schill made a geological map of the area, Scale 1 : 50,000, as early as 1862. This work is sometimes lacking in details and accuracy. He did not separate the eruptive gneiss of Albbruck from the injection gneisses of the locality and omitted many of the aplite and lamprophyre dykes. The gneiss along the Schurlebach is wrongly mapped, being shown to extend continuously as far as Bohland. He makes no mention of the anorthosites, and he did not map the amphibolites opposite the saw-mills in Ibach. Later on, the area was visited by many geologists, but no important publication was made.

B. GEOLOGY.

The general geological and tectonic characters of the whole of the Black Forest are to a very remarkable extent reflected in the area of which a petrographical and geological description is to be given in the following pages. For the sake of clearness, therefore, it will be necessary to begin with a short account of the geology of the Black Forest as a whole, and especially of the Carboniferous and earlier ages with which we shall mostly be occupied.

On the other hand, the Black Forest occupies a peculiar central position in the land mass of Europe, and for this reason it will not be out of place if a very brief account of the geology of Europe (from the Carboniferous downwards) be added, so as to correlate the geology of the Black Forest with the more general conditions of the entire continent.

Position of the Black Forest in the Geological System of Europe.

In his "Bau der Erde"[1] Prof. Kober, of Vienna, has given an interesting account of the geological structure of Europe and other continental masses. He has divided each of the continental land masses into the three following geological units:—

(1) The Archæides.
(2) The Palæoides.
(3) The Mesoides.

(1) Those land masses that were formed in the Archæan age, and have undergone no geological disturbances since then, are

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[1] See lit. 30.

included under the term Archæides. In Europe the Russian plateau, together with the Scandinavian shield, belong to this group.

(2) Those land masses that were formed in Palæozoic times, and have remained more or less undisturbed until to-day, are termed Palæoides. This term is synonymous with Penk's "Palæozoische Hochalpen," and Süss's "Altaiden." The Palæoides have been subdivided into (i) the Caledonian; (ii) the Armorican; and (iii) the Hercynian or Varistic mountain types.

(3) Under the term Mesoides are to be included all those mountains which possess a Palæoidal origin, but have undergone further disturbances in the Mesozoic–Tertiary period. Their present condition is the result of various geological factors, and particularly of geosyncline activity in this age. The Mesoides, therefore, are characterised by regional and dynamic metamorphism, overlaps, etc. This type of mountain has been subdivided into (i) the Dinarides, and (ii) the Alpides.

Of all these mountain systems the *Palæoides* are of especial interest for the geology of the Black Forest. The latter consists mostly of igneous rocks, which appeared in the sequence of tectonic activity in the Permo-Carboniferous period, during which age similar activity and magmatic intrusions also took place in the Alps (Aar-massif, Gotthard-massif). Southern England, Central and Northern France and Central Germany are further examples of Palæoid mountains.[1]

As mentioned above, the Palæoides have been subdivided into three groups, viz., the Caledonian, Armorican and Hercynian. The general characters of these three types of mountains may be summed up as follows:—

To the Caledonian mountain type belong the mountains of Norway, Scotland, N. England, Wales, most of Ireland, as well as, perhaps, the Alleghany and Blue Ridge Mountains of N. America. They possess S.W.–N.E. strike direction, and according to Gosselet they are supposed to be of Cambrian-Silurian age.

The mountains known as the Armorican system radiate from the central plateau of France to the N.W., and extend over Brittany, Devonshire, S.W. Ireland, and beyond the Atlantic.

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[1] Examples are also available from Asia. "Permo-Carboniferous rocks of both Eastern and Western Yunnan are characterised by the presence of contemporaneous igneous rocks" [Andesite]. J. Coggin Brown, "Geology of Yunnan." Recd. Geol. Surv. of India, Vol. LIV, Pt. I, 1922, p. 74.

They have characteristics which are quite different from those of the Caledonian type. They are of Carboniferous age, *i.e.*, they are younger than the Caledonians from which they are, perhaps, separated in the north by a sharp discordance.

Of the same age as the Armorican mountains, but radiating to the N.E. from the French central plateau, are the mountains known as Hercynian, or Varistic.

The individual ranges belonging to this group and possessing the same N.E. strike direction are said to be of Hercynian type. These Hercynian mountains extended over N.E. France, Southern and Middle Germany, Bohemia and Poland. Innumerable surviving horsts of these Hercynian mountains still stand intact in the shape of granite-gneiss complexes, and spread over great areas in England, Germany and France. The Albtal massif belonging to the most southerly granite-gneiss complex of Germany also constitutes such a Hercynian relict.

To these horsts belong for instance :—

(1) *In Great Britain.*—The mountains of Devonshire, including the granite massifs of Dartmoor, Bodmin Moor, St. Austell, Land's End and the Scilly Islands, etc.

(2) *In France.*—Vosges Mountains, the Central Plateau and the mountains of Brittany, etc.

(3) *In Germany.*—Rheinische Schiefergebirge, Harz Mountains, Erzgebirge, the Black Forest, Fichtelgebirge, etc.

The horst of the Black Forest is the most southerly occurrence in Germany ; it includes a number of subsidiary units, viz. :—

In the Northern Black Forest	Murgtal massif.
In the Middle	Triberger massif. Eisenbacher massif.
In the South	Schluchsee massif. Albtal massif. Blauen massif.

According to Kayser the so-called Central massif of the Central and Western Alps, as well as the mountains of the Iberian Peninsula, also belong to the Hercynian mountains.[1]

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[1] See lit. 28.

Geological Character of the Palæoid Mountain System.

The various remnant horsts of the Palæoides have been the object of detailed studies by many distinguished geologists both of Great Britain and of the Continent. Their work reveals the fact that certain general geological and petrographical features constantly recur throughout the system, and that points hundreds of miles apart, Cornwall and the Harz, for instance, possess astonishing geological similarities. We are led to suppose that not only the general geological and tectonic factors, but also the same chemical and physical conditions have regulated the formation and subsequent deformation of the system as a whole.

Prof. Niggli has summed up the general geological and petrographical characters of the whole of the Hercynian system as follows :—

Everywhere there can be seen :

A. At the base, the " Grundgebirge," the oldest formations in these regions, consisting of various kinds of gneisses, phyllites and amphibolites (Hornblende gneiss), etc.

B. The intermediate formation, or the formations of the " Uebergangsgebirge," consisting of phyllites, and sometimes marble and even pure sediments. The whole lies discordantly on the eroded surface of the last named.

C. The rocks of intrusive and extrusive origin consisting largely of granite massifs with dykes of aplite, granite-porphyry and lamprophyre, which traverse the granite and gneiss.

Over the granite-gneiss complex lie the Mesozoic sediments of the *Deckgebirge* or " roof formations " which are separated from the former by a discordance. Above these again are occasionally to be found Tertiary volcanic rocks and boulder beds of the Glacial age.

These general geological characters, and especially those of the granite-gneiss complex, may be illustrated by the following examples :—

IN ENGLAND.

Cornwall and Devonshire.

A & B. Devonian slates,[1] Kulm measures.[2] Typical diallagic gabbros occur in the Lizard district in Cornwall. In places these rocks are much foliated. The felspars have been saussuritised and the augites uralitised.[1] In Devonshire, the Middle Devonian volcanic series consists of basaltic lavas weathered to a rusty colour and, together with the associated tuffs, has been frequently sheared into schistose rocks.[2] Olivine basalt of Permian age is found in the neighbourhood of Exeter.[3] It intrudes into the carboniferous limestone.

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[1] Hatch, " Textbook of Petrology," 1914, p. 374.

[2] Ibid., p. 350.

C. The large granite massifs, especially of Dartmoor, Brown Willy (Bodmin Moor), St. Austell, Falmouth and Land's End, with large phenocrysts of white alkali felspars disposed in a parallel arrangement. These granite massifs are occasionally found to be penetrated by a finer grained and more acid granite—undoubtedly younger than the porphyritic granite.[4] Acid dykes, locally known as "elvans," are abundant in Devon and Cornwall.[5] They traverse both the Devonian slates and granite bosses. Petrographically, they are acid granites and porphyrites.[6] Typical aplite occurs in connection with Dartmoor granite.[7] Excellent examples of lamprophyre are occasionally met with.[8]

The phonolite of Wolf's Rock (Tertiary),[9] off the coast of Cornwall, is the only representative of nepheline rocks in England.

IN GERMANY.

I. *Erzgebirge*.[10]

A & B. *a*. Clayey sediments, coarse grained sediments and quartz schists of Cambrian and Silurian ages.

b. Diabase, shales, etc.

Folding and metamorphism of *a* and *b*.

C. Granite intrusion.

II. *Fichtelgebirge*.[11],[12]

A & B. *a*. The lowest known formations are here the marble rocks of Wunsidel. Above these comes phyllite, which is supposed to be a continuation of the phyllite-zone in the Erzgebirge.

b. Keratophyre, Pikrite, Diabase.

Both *a* and *b* are of Cambrian and Silurian ages.

C. Granite.

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[1] Hatch, "Textbook of Petrology," 1914, p. 417.
[2] Ibid., p. 419.
[3] Ibid., p. 325.
[4] Ibid., p. 325.
[5] Ibid., p. 356.
[6] Ibid., 356.
[7] Ibid., 387.
[8] Ibid., p. 392.
[9] Ibid., p. 406.
[10] Reinisch. Entstehung u. Bau der deutsch. Mit. Gebirge. See lit. 52.
[11] Reinisch. See lit. 52, p. 104.
[12] Niggli, Lecture Notes.

III. *The Harz.*[1]

A & B. Grauwacke, Kieselschiefer, accompanied by the diorite of Ilsenberg (Silurian), quartz–schist, diabase, the famous kersantite of Blankenberg, and limestone .. .. (Devonian)

The famous limestones with silver mines. (Lower Carboniferous)

C. Granite.

IV. *The Black Forest.*[2]

A & B. Rench gneiss with amphibolites and eruptive gneiss (Silurian)

Schists (Lenzkirch) and intrusion of basic rocks (serpentine, etc.). Beginning of the orogenic movements .. .. Devon (?)

C. Intrusion of the granite massif and the dykes. Conglomerate, arcose, etc. Completion of the hercynian folding .. (Kulm or Lower Carboniferous)

In France.

The Vosges.[3]

Profiles analogous to the examples given above have been found in the Vosges mountains, especially in the Steig and Brenntal areas. At the last-named place the following profile may be observed.

A. & B. Marble, sand, melaphyre metamorphosed into shales quartzite, amphibolite, etc. .. (Devonian)
Limestone, diabase (labradorite, etc., of the Vosges) (Lower Carboniferous)
Folding.

C. Granite.

Fossils of the Silurian and Devonian ages have been found in the "Übergangsgebirge" at Steig.[4]

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[1] Reinisch. See lit. 52, p. 182.

[2] Deecke, Morphologie von Baden, Berlin, 1918, p. 14.

[3] See lit. 52.

[4] Niggli, Lecture Notes.

Geological and Physico-chemical Phenomena Common to the Whole of the Palæoides.

The geological and physico-chemical phenomena common to all the above-mentioned formations may be summed up as follows :—

(1) Folding began first in the Silurian and Devonian periods, metamorphosing previously existing sedimentary and igneous rocks. Almost simultaneously or a little later there took place intrusions or extrusions of a basic magma, e.g., diorite in E. Brocken, gabbro in Ilsestein, Harz ; gabbro, olivine-basalt, etc., in Cornwall. The generally basic character of these rocks indicates that at most very slight differentiation had taken place at the time of intrusion.

(2) Orogenic movement. The sediments and basic intrusions are folded and rendered partly or fully schistose.

(3) As the folding was proceeding granite-magma was intruding into the anticlinal vaults of the gneiss under its own pressure, i.e., under the pressure due to volatile fluxes contained in it. According to Niggli this took place in Carboniferous times[1].

(4) A gravitative differentiation[2] was all the time taking place in the granite magma leading to the formation of a basic substratum. To bring about a gravitative adjustment, most of the heavier basic differentiate sank down.

(5) The remaining portion was caught up by the outpouring granite mass and raised to higher levels as basic enclaves in the chief granitic rocks. These enclaves are lamprophyric or syenitic in composition and are much more acid than the gabbroid mother magma.

(6) The anticlines were completed in the Carboniferous time. According to Deecke[3] the gneisses were metamorphosed before the Carboniferous age. In a last phase the granite intruded into the finished anticlines. Subsequently no more important pressing and squeezing took place, and for this reason, the granite having attained this stage, crystallised slowly, and quietly, developing large phenocrysts of felspar, and formed the homogeneous laccoliths as exposed to-day.

(7) Traces of flow movement during solidification are apparently of very wide occurrence. Thus the felspar phenocrysts in the Albtal granite regularly show a parallel arrangement (Fig. 11), the general

[1] Niggli, Die Differentiation im Südschwarzwald, Centralblatt, 1911, 438.

[2] Daly. See lit. 11. Niggli, lits. 38, 39, 43, etc.

[3] Geologie von Baden. Bd. 1, p. 56.

direction adhered to (c′ axis of the felspar) being visible also in the arrangement of the biotites and basic enclaves. Similar phenomena are also reported from Cornwall.[1]

(8) As the solidification of the granite mass proceeded, increasing quantities of volatile substances (pneumatolytic constituents) and acid differentiates collected.

The upper surface of the granite was already solidified and therefore offered no means of outlet. These components remained enclosed under constantly increasing vapour tension. Cracks and fissures subsequently formed in the granite mass as the result of cooling and contraction, were invaded by these differentiates giving rise to pegmatites, aplites and granite-porphyry.[2] The basic substratum gave rise to lamprophyres. The relative age of these dykes is an interesting question to which later reference will be made.

Lastly, reference must be made to the young Tertiary intrusives[3] in all these horst-regions which show sodic character (*vide* phonolites of Hohenthwiel, leucit basalt of Eifel, Kaiserstuhl; Neph-Basalt of Katzenbuckel; phonolite of Wolfrock, off the coast of Cornwall) in contrast to the calcalkalic (i.e., Pacific) type, which characterizes the Palæozoic rocks of these areas.

The whole complex of phenomena offers an object lesson, on a gigantic scale, of the intimate relation between geological, tectonic and magmatic processes. Especially P. Niggli has repeatedly urged this point[4] and shown that the association of petrographic types is never accidental but always the definite outcome of preceeding geological events.

[1] Hatch, p. 325, lit. 24.

[2] Niggli, Die Differ. im Südschwarzwald, Centralblatt, 1911, p. 438.

[3] U. Grubenmann. "Die Basalte des Hegau's" Dissertation. Zurich. 1886.
J. Erb. Diss. Zurich. 1900.

[4] Niggli. Petrog. Prov. der Schweiz. Also see lits. 39, 38, etc.

II. LOCAL GEOLOGY OF TIEFENSTEIN.

The rocks in the Tiefenstein area may conveniently be divided into the following groups :—

A. Gneisses of Archaeian, Silurian and Devonian ages, constituting the Grundgebirge.
C. The Rocks of the granite laccolith.
D. The Triassic Sediments constituting the "Deckgebirge." (The lettering corresponds to the summaries on p. 5.)
B. The "Uebergangsgebirge" is almost absent in the Black Forest.

A (I.) THE GRUNDGEBIRGE.

The oldest rocks in this area are the *sedimentary paragneisses* extending all along the southern boundary (the Rhine) from Hauenstein to the valley of the Schurlebach, then ultimately vanishing under Triassic sandstone. No further occurrences of these rocks are met with in an easterly direction from here along the Rhine. In this southern part it has been strongly injected by an aplitic eruptive gneiss known as the Granulite of Albbruck, which appears in a long narrow zone from Mühlebach to Schurlebach, attaining its greatest width in the quarry at Albbruck. The veins of lit-par-lit injection from the aplitic granulite gneiss become thicker and more common as we approach the main body of the eruptive gneisses.

Further away from the eruptive gneisses the veins become rarer and finer, the gneisses finally losing all signs of injective influence from the eruptive rock. The unaltered (sedimentary) gneiss is known here as " Rench " gneiss. The injected sediments have been, on the other hand, called " Injection gneiss." The injected rock occupies by far the greatest portion of the gneiss area. Not only the eruptive gneiss of Albbruck, but also many sills and dykes of eruptive gneisses, probably apophysæ of the same main body of which the Albbruck-gneiss is the chief representative, have injected the old sediments and metamorphosed them (Fig. 2.) These manifold sources of injection greatly complicate the location of the boundary between para (sedimentary) and injection gneisses.

Circumstances prevented me from undertaking the detailed mapping of the Schapbach and injection-gneisses ; both are shaded

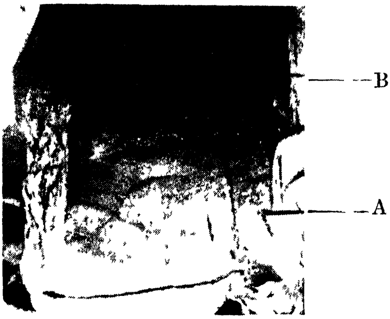

Fig. 2.

SEDIMENTARY GNEISS INJECTED BY ERUPTIVE GNEISS.

A. Eruptive Gneiss (Granulite) B. Injection Gneiss which is injected by veins that originate from A. About $\frac{1}{27}$ Natural size.

[*Facing page* 10.

alike in the map. The following details may serve to characterize the injection veins. They vary in breadth from several centimetres to microscopic dimensions. Usually the veins are regular, but sometimes, as in the quarry of Hauenstein, they assume a beaded appearance, giving rise to an "Augen-gneiss" structure in the sediments. The very fine veins are sometimes so numerous as to cause the sediment to assume the structure of an igneous rock. In Grubenmann's words it may be said : "Dort hat in sehr ausgedehnter und intensiver Weise ein bis ins kleinste und Einzelnste gehendes Eindringen (das heisst eine Injektion) von magmatischem Material in schon vorhandene ältere Gesteine stattgefunden." (See lit. 20.)

The colour of the veins is not the same in all parts. From the Rhine to a little above the point where the Rickenbach flows into the Alb, the veins are all of a pink or fleshy colour, similar to that of the eruptive gneiss or granulite of Albbruck. As one proceeds further northwards along the cutting of the canal of the hydro-electric power works, belonging to the paper factory, Albbruck, the veins locally become white or translucent.

From the Rhine, northwards, the gneiss extends to the southern boundary of the granite massif, forming the lowest and oldest formation of the area. According to Sauer they are of Archaeian age[1]; Deecke considers them to be Devonian and older.[2]

The gneiss is occasionally penetrated by the eruptive gneiss of Albbruck or covered by boulder beds (as at Schacken, Kiesenbach, etc.) or sandstone (as in Etzwihl, etc.). The gneiss in the vicinity of its contact with the granite (about 300 metres from the Wirtshaus Tiefenstein, near the Albthal road) is injected by the latter, some large intrusions also occurring. This fact is interesting in view of the opinion held by Schwenkel[3] that no signs of injection between granite and gneiss are to be found. The gneiss forming the roof of the granite intrusions (about 50 metres to 150 metres N. of the first tunnel) is remarkable for its crushed condition.

Beyond the granite laccolith, in the neighbourhood of Niedermühle and Vogelbach, the gneiss reappears and is here also injected by the granite.

At certain places in the Ibach Valley the paragneiss is characterised by peculiar columnar texture. Paragneiss with similar texture has also been reported by Suter from the Murgtal.

The general Strike direction of the paragneiss in this part of the Black Forest is 310° N.W., and the Dip is 70° S.W.

[1] Sauer lit. 58. [2] Deecke lit. 13. [3] Schwenkel. See lit. 59.

The *eruptive gneiss* of Albbruck, best exposed in the government quarry, is the next oldest rock of the area. As already mentioned it injects the sedimentary gneisses. Like the latter, it is completely metamorphosed and possesses a parallel structure like that found in the border region of many granite and syenite rocks of the S. Black Forest; gneisses, with such characteristics, were named Schapbach gneiss.[1] It is therefore evidently older than the non-schistose rocks of the area. It is probably also older than the amphibolites (see pp. 13, 30). These latter, though metamorphosed, have a rather sharp boundary against the sedimentary gneisses and have nowhere considerably injected the same. Direct contact between eruptive gneisses and amphibolites has not yet been found.

The main body of the eruptive gneiss extends from the Alb, between the railway viaduct and about 50 metres N. of the last dam of the paper factory, to the "Buntsandsteine," in the Schurlebach, under which it then vanishes. Most probably the 25 metre wide dyke of eruptive gneiss among the forests near the small bridge over the Mühlebach, 500 metres N. of the factory in Hauenstein, is the westerly continuation of this strip. Sills and lit-par-lit intrusions of this gneiss are found widely distributed among the injection gneisses.

The eruptive gneiss of Albbruck is well exposed in the beds of the Alb, Hölzlibach, Schurlebach and in the old abandoned quarry by the Dogern-Birkingen road, about 200 metres N. of the railway station at Dogern. In the other part of the strip, extending from Mühlebach to Schurlebach, it is either covered by the gneiss or boulder beds, or buried under detritus of its own weathering products which are very difficult to distinguish from those of the injection gneisses.

In the railway quarry Albbruck on the N. boundary, in the valley of the Alb on the N.W. boundary and in the Hölzlibach and Schurlebach on the S. boundary, it is found to end with a Lamprophyre-dyke.

The dykes are not schistose and are therefore younger than the eruptive gneiss.

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[1] Sauer, Ueber das Vorkommen von Parallel-Struktur an Massivgraniten des Schwarzwaldes; Sitzungsberichte d. Oberrheinischen Geologen Vereins, 1904.

A (II.) THE PRE-GRANITIC BASIC INTRUSIONS.

They are represented in the area around Tiefenstein by amphibolites and anorthosites.

I. AMPHIBOLITES.

A. Tiefenstein.—The only outcrop occurs opposite the inn. It is almost entirely surrounded by granite, only the south western corner being for a short distance in contact with gneiss. It is closely connected with anorthosites (see below) and is traversed by innumerable pegmatite and quartz veins.

B. Niedermühle.—Amphibolites also occur on the northern boundary of the granite about 1,500 metres south of Niedermühle. They occur there just on the boundary of the granite in the Albthal and in the Ibach valley opposite the saw-mill, thus defining a zone of north-westerly direction which is probably continuous. The amphibolites are highly injected with felspathic and pegmatitic veins which constitute the natural cleavage surfaces of the rock.

2. ANORTHOSITES.

Anorthosite, which is one of the very rare rocks of Germany, is found here, as mentioned above in a small occurrence of about 1,000m^2 in the amphibolites of Tiefenstein (see Fig. 5). Its strike direction is N.W.–S.E. It is mostly massive and fresh ; on its southern boundary, resorption has taken place between amphibolite and anorthosite. From this point a gradual transition between amphibolite to anorthosite is traceable. Near its upper boundary it is somewhat schistose, which proves that differential movements have occurred subsequent to its formation. The anorthosite is traversed near its western boundary by veins of quartz and pegmatite.

C. THE ROCKS OF THE GRANITE LACCOLITH.

The granitic rocks form a large laccolith extending from the Alb to Wiesen in the southern Black Forest, and usually known here as Albtal Massif or Schluchsee Massif. The age of the laccolith, according to Niggli[1] and Erdmannsdörffer,[2] is Carboniferous, and

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[1] Die Differentiation im Südschwarzwald, Centralblatt f. Geol., 1911, p. 438.

[2] Die Entstehung der Schwarzwalder Gneisse, Geol. Rundschau, Bd. IV, Heft 5 and 6, 1913.

Deecke[1] specifies Kulm or Lower Carboniferous. Besides typical granite, innumerable dykes of aplite, granite-porphyry and lamprophyre occur,* and a very characteristic feature of the occurrence is constituted by various basic and acid enclaves in the main granitic rock. The granite is of a porphyritic type with largely developed phenocrysts of orthoclase. The mineral composition of the granite varies somewhat and various types may be distinguished according to the volume percentages of mica, quartz, and orthoclase, as has been proposed by Richardson for the St. Austell granite massif of Cornwall.[2]

All the above mentioned (A & C) rocks constitute products of the Hercynian magmatic and orogenic activities. Typical for all the dykes of this series is that they are found never to extend very far into the Trias. According to Heim,[3] they are found never to extend even as far as Trias. Niggli[4] puts the limit of the Hercynian post-volcanic activities in the Wellenkalk series of the Middle Trias. In my area the coarse grained granite-porphyry dyke of Niedermühle is found to extend as far as the Buntsandstein, near Oberalpen.

D. DECKGEBIRGE.

We now proceed to discuss the rocks of the Deckgebirge of the locality.

On the granite, but separated by a well-marked discordance, rests the *Buntsandstein,* i.e., the oldest Trias of Germanic facies. I have collected hand specimens of the sandstone in contact with corroded crystals of felspar. This proves that the Buntsandstein was deposited on the weathered surface of the granite. Carboniferous sediments are very rare in the S. Black Forest. This shows either, that the area was never submerged by the Carboniferous sea and that it had already a hilly countenance in the Carboniferous age, or that there took place a great erosion in the late Carboniferous period.

In the Tiefenstein area no noteworthy occurrences of Buntsandstein are to be found W. of the Alb. The small areas of sandstone at Oberwihl and Niederwihl, etc., are sometimes but a few inches in thickness, and the rock is very difficult to distinguish from the ordinary detritus products of granite.

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* In all, I have been able to discover 11 aplite dykes, 20 granite-porphyry dykes, 47 lamprophyre dykes.

[1] Deecke—Morphologie von Baden.

[2] W. A. Richardson: A micrometric study of the St. Austell granite, Cornwall. Q.J.G. Society, London, Vol. LXXIX, part 4, 1923, p. 546.

[3] Heim, Geologie der Schweiz, Vol. 1, p. 443.

[4] Niggli—Lecture Notes.

In the E. of the Alb the Buntsandstein is found all along the valley of Steinbach. It occurs at first on the high slopes near Etzwil-Riedacker-Tanne ; from the Mühle onwards it is found in the bed of the rivulet separating the granite from the Muschelkalk and possesses a thickness of about 55 metres. In this area the boundary between granite and sandstone may easily be traced, even when covered by forest or obliterated by ploughing. The soil in the granite area contains remnants of felspar as well as occasional boulders of unaltered granite. Much more difficult to locate in this valley is the boundary between sandstone and the next following series (the Muschelkalk), commencing with the so-called Wellenkalk group. The lowest bed of the latter has the nature of clay beds which intermingle intimately with the detritus and humus derived from the sandstone, thus obliterating the transition.

In the Buch-Birndorf area the sandstone is locally exposed at Buch, Fluhhölzle, etc. The southern boundary of the rock is here in contact with the boulder beds. In the N. the transition to Wellenkalk is rendered quite distinct by the erosion of the clay beds, which gives rise to deep furrows separating the sandstone from the limestone of the middle Muschelkalk. In the cup-shaped erosion furrows signs of faults seem to be indicated by frequently recurring sinkages in the soil on the side of the sandstone (N. of Birndorf).

The valley of Schurlebach constitutes the finest exposure of the sandstone in this area. Here the rock can be followed uninterruptedly from a little S. of Birkingen to Dogern.

An E.W. section through the valley shows the following profile. In the deeper part (river bed) occur the last outcrops of the gneisses in the east, constituting two distinct lenses, one at Dogern, just behind the village, and the other near Grundacker. The southern one contains both eruptive and injection gneisses, while the northern one contains eruptive gneiss, injection gneiss and a granite-porphyry dyke.

Above the gneiss sandstone is met with. The rock is at first of the nature of a green, coarse-grained calcareous sandstone similar to arcose.

Above this again appear layers of a ferruginous sandstone about 20 metres thick. This rock can best be studied in the forest on the W. slope of the Schurlebach, near " Z " of Vogelplatz. It is of a deep red colour—being almost of the appearance of weathered hæmatite.

The ferruginous sandstone is, in its turn, substituted by pure white sandstone which constitutes the highest sandbeds in the slope. At certain places (as in Birndorf and in the valley of the Schurlebach) the lowest beds of this member of the Buntsandstein contain *carneol*. Veins of *barytes*, constituting the last hydrothermal injections from the granite, are also found in connection with these occurrences (for instance, in Birndorf).

The first two sandstones may be supposed to have been deposited in inland seas, the last is probably a terrestrial deposit (desert sand).

The thickness of the three layers is not constant over the whole area. Proceeding northwards and N.W. a gradual thinning of the two lower members may be observed. This takes place most rapidly for the lowest bed of green sandstone, which disappears entirely as soon as Tanne. Here we have the sequence—white sandstone, red sandstone, granite. At more northerly localities the red sandstone also becomes more and more reduced. Traces are still to be found in the quarry east of the last house in the Steinbach, near the place where the Unteralpen-Niedermühle road crosses the river, as well as in the quarry at Rottenstil, whereas it is completely missing in the Niederwihl and Oberalpen areas. The white sandstone here rests directly on granite.

These facts are of peculiar interest, in view of the opinion often expressed by the Black Forest geologists, that an *oceanic transgression* took place in the S.E. Black Forest during the early Trias. (See profile I.)

As may be deduced from the white sandstone, an arid period followed the transgression, the ocean being gradually dried up. The expanse of water was gradually reduced to certain deep basins in which evaporation and concentration of the salt took place, ultimately leading to *saline deposits*, as in the neighbourhood of Zurzach. The general Dip of the Buntsandstein is S.E. 4°.

As previously mentioned, the Buntsandstein is followed by the clay beds of the *Wellenkalk* horizon of the *Muschelkalk*. The latter formation attains in all a thickness of about 120 metres, and is well developed in the highlands between Etzwil-Buch-Birkingen in the south, and Mühle-Unteralpen-Dörfle-Oberalpen in the north, as white limestone. The Muschelkalk dips to the east. No detailed studies of the sedimentary rocks could be undertaken.

It may finally be mentioned that fluorite and barytes veins are frequently to be met with in the Buntsandstein. I have collected crystals of milkquartz from the Muschelkalk bank, near Waldshut, also galenite from the same rock, near Dogern. These products indicate that the magmatic activity was not concluded in the Carboniferous period with the formation of granite and the dykes belonging to it, but extended over the Mesozoic period. The silicifications in the limestone in this area, as well as the eruption of phonolites, etc., in the neighbouring volcanoes in the Hegau,[1] likewise tend to prove this point. Further details may be found in the works of Andrée.[2]

The most recent geological formations in this area are the *Diluvial Boulder Beds* consisting of sand, clay and boulders. They constitute a most important source of sand supply for the people of the locality. They have buried under them a considerable portion of the gneiss and Buntsandstein. When of sufficient thickness (1 metre or more), I have included them on the map.

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[1] See lits 13 (a) and 20 (a).

[2] See lit. 1.

III. ROCKS OF THE "GRUNDGEBIRGE."

A. THE GNEISSES.

On page 10 I have dealt with the geological aspects of the gneisses in the Tiefenstein area. The southern Black Forest gneisses have been studied in detail by P. Niggli,[1] and recently by my friend Suter.[2]

These authors have given analyses of various types of the para-gneisses of the S. Black Forest, and for this reason no further chemical studies of these rocks were undertaken by me. It will, however, be necessary to give a general summary of the megascopical and microscopical characters of some typical examples of the gneisses. A new chemical analysis of ortho-gneiss has, however, been carried out by me. It will be convenient first to study the gneisses of almost wholly sedimentary origin, and the gneisses of eruptive origin separately, and then proceed to the highly injected gneisses in which characteristics of both the preceding sorts are to be found.

I. Sedimentary Gneisses.

As may be seen from the mineralogical composition given below, a part of these rocks may also be termed

(a) *Sillimanite-Cordierite-Gneiss.*

Megascopically it is a brownish-black rock, consisting of parallel but gently undulating and usually closed layers of biotite and quartz-felspar. The parallelism is due both to the original stratification and to the lamellar character of the newly-formed biotite.

Under the microscope the rock is found to consist of quartz-felspar and biotite all recrystallized under stress and therefore elongated. Only the biotite is arranged with any particular crystallographic orientation along the direction of foliation.

Cordierite, sillimanite, orthite, zircon, zoisite, rutile, chlorite, muscovite, leucoxene, magnetite are important accessory minerals of the rock.

The *quartz*, which in ordinary polarized light appears as patches of apparently uniform character, is seen between crossed Nicols to consist of innumerable grains, all crushed and sutured with one another. The *felspar*, being less rigid, has withstood the strain more successfully than the quartz. It possesses irregular contours and stands out rather conspicuously in the finely granular and banded matrix of quartz. Both the quartz and felspar possess undulose extinction; the felspars being often distinctly bent. The biotites are arranged with their $n\alpha$ parallel or subparallel to each other. In many cases they have yielded by bending, but their ends are often disintegrated by the stress, presenting a fringed appearance.

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[1] Niggli. See lit. 44.

[2] Suter. See lit. 64.

The layers rich in biotite, together with the quartz accompanying them, have a crushed hornfels structure, while the layers of quartz-felspar alternating with the former are blastoaplitic to granoblastic. Such structure is usually known as the injection structure.

The rock in its present state, as described above, is the outcome of repeated metamorphic processes. In the first instance katametamorphism of a clayey sedimentary rock produced the biotite gneiss; at a later period earth movements took place, which to some extent crushed the gneiss and were, perhaps, also the reason of the magmatic movement from which the injection of the rock resulted. That the orogenic movement continued after the solidification of the injection veins can be judged from the fact that the latter also show signs of slight crushing.

The *biotite* is brown and pleochroic. The absorption colours vary between

$$n\gamma = n\beta > n\alpha$$

Brown colourless to light brown.

Chloritisation has usually taken place in the margins. Along with chlorite some of the individuals have separated rutile in the form of radiating needles forming the so-called "Sagenite gewebe." Smoky, opaque patches consisting of leucoxene are of similar origin. Zircon with pleochroic halo is a further common inclusion. Apatite is also frequently met with.

Felspars.—The potassium felspar usually appears in the form of perthitic intergrowth with albite. Typical microcline, with cross-hatching, is occasionally met with.

Plagioclase appears as independent individuals of the following properties. They are polysynthetically twinned, optically positive, their extinction angles on sections about perpendicular to $n\alpha$, against the twinning lines, *i.e.*, against the trace of $(010) = -20°$. These individuals are therefore closely related to albite.

Apatite usually occurs in round or elliptical grains.

Zoisite occurs in grains with high refractive index. It possesses grey interference colours, rough surface, straight extinction and biaxial positive character.

Sericite occurs as a decomposition product of orthoclase and biotite in scales or aggregations.

Cordierite occurs in colourless grains with irregular outline. It possesses no cleavage lines, but the surface seems to show minute striations. Its refractive index is lower than that of quartz and plagioclase and greater than that of orthoclase, and it is biaxial and negative. It is full of needles of sillimanite.

Sillimanite.—Innumerable colourless needles of this mineral occur embedded in cordierite, as well as in felspar and quartz. Not infrequently the needles are clustered at the decomposed ends of biotite.

Magnetite.—It occurs closely associated with chlorite, sagenite, etc., in the decomposed biotite.

The *zircon* inclusions in biotite possess high relief, prismatic cleavage lines and high interference colours.

The *orthite* inclusions, which also possess pleochroic haloes, are easily distinguished from the last by their much lower interference colour.

The mineral paragenesis of this rock is that of a typical Katagneiss, rich in alumina and is probably of sedimentary origin. It corresponds to the typical members of Group II in Grubenmann's classification.

The following types, which are of very common occurrence, may be quoted as examples of sedimentary gneiss with a compact and massive texture resembling that of igneous rocks.

(*b*) *Cornubianite Gneiss.*

The particular specimen examined was collected from the quarry at Hauenstein. The hand specimen was quite fresh and compact, and in parts possesses conchoidal fracture. The colour may be called bluish grey or light blue. The structure is that of a hornfels.

It consists of layers of very minute scales of biotite, about ½ mm across, alternating with a light blue mixture of quartz-felspar.

Under the microscope, the rock is found to consist of a homœoblastic aggregate of quartz, felspar and biotite, hornblende being also occasionally present. Orthite, chlorite, zircon, pyrites, pyrrhotite and apatite are the common accessories.

The structure is, on the whole, like that of a coarse-grained hornfels nearing granoblastic appearance. The natural appearance of a mica-gneiss consisting of alternate bands of quartz-felspar and biotite is, on the whole, not lost, but there are parts where the rock consists of about 65 per cent. of quartz, 30 per cent. of felspar, with only about 5 per cent. of disseminated biotite.

Quartz.—On an average it forms about 55 per cent. of the whole rock. It is usually intergrown with felspar and possesses no crystalline outline. It shows undulating extinction.

Felspars.—On an average they form about 35 per cent. of the whole rock. They consist of orthoclase, microcline and plagioclase.

The microcline possesses distinct cross-hatching.

The plagioclase is polysynthetically twinned. Its twinning lamellæ are not very broad, its refractive index is lower than that of quartz, it is optically positive, and it shows an extinction angle of about +3 deg. on the face (001). It is therefore albite.

Biotite.—It is brown and pleochroic.

$$n\gamma = n\beta > n\alpha$$

dark brown or deep brown   light brown to colourless

Extinction parallel to the cleavage lines. It contains inclusions of apatite, orthite, zircon, etc.

Hornblende is the other important coloured component of the rock. It occurs in grass-green pleochroic patches without any crystalline outline whatever. The cleavage lines are well developed. Its extinction angle $c : n\gamma =$ about 16 deg. At many places a gradual transition between hornblende and biotite is observed. The hornblende has apparently been changed into biotite.

Orthite.—It occurs together with biotite, either in grains as small inclusions, or in large brown patches. It possesses pleochroic haloes, straight extinction along the well-developed cleavage lines and a straw-yellow interference colour ($n\gamma - n\alpha =$ about 0.010 to 0.015). The pleochroism is generally very weak.

Pyrites and Pyrrhotite.—The former is characterized by its shining yellow and the latter by its copper red colour in reflected light.

It will have been noticed that the rock (from the quarry at Hauenstein), as described above, possesses the essential features of a cornubianite gneiss. This term was first used by Boase[1] for a fine-grained, compact mica gneiss found in Cornubia, Cornwall, and very poor in coloured constituents. Its structure was similar to that of a hornfels (see Grubenmann "Die Kristallinen Schiefer" II. Ed. Tafel III, Fig. II). Rocks closely corresponding to the above definition are frequently met with in the Black Forest (Fischer, Schill,[2] Suter), and examples are also known in Saxony.[3]

Two analyses of this rock are published in Grubenmann-Niggli "Die Gesteinsmetamorphose" III. Ed., 1924, p. 74. They show that the cornubianite gneiss corresponds with the rocks mentioned by Grubenmann as para-derivatives of group I, in the Katazone.

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[1] F. Zirkel Bd. II Lehrbuch der Petrographie, 1858.

[2] Fischer "Ueber die Verbreitung der Triklinoedrischen Feldspäte im Schwarzwald," p. 456. Schill, loc. cit. p. 58. Suter. Dissertation. Zürich, 1924.

[3] Petrographical Hand-Specimens. Eid. Tech. Hoch. Zch.

(c) *Diopside Hornfels.*

At Hölzlibach, opposite the lower end of the southern granulite outcrop, occurs a lense consisting of a compact, middle-grained, light grey rock forming an inclusion in the gneisses. In the hand-specimen it is found to consist of quartz, felspar and light green diopside. Its metamorphic character cannot be determined in the hand-specimen. Under the microscope also the rock shows a structure which is rather that of a fine-grained hypidiomorphic rock than that of a hornfels.

Microscopically, the rock is found to consist of quartz, diopside, felspar and zircon. Apatite is an accessory.

Quartz occurs in grains sutured with one another. It shows strain shadows.

Felspars.—The orthoclase is all perthitic. Microcline is very rarely found. The plagioclase felspar possesses the following characteristics :—

It is polysynthetically twinned ; its refractive index is equal to that of quartz ; it is optically biaxial and negative. These characters correspond with those of basic oligoclase-andesine with a composition of about $Ab_{70}An_{30}$.

Diopside.—In the slide it appears greenish, almost colourless. Refractive index and interference colours high ; good prismatic cleavage lines intersecting at about 90 deg. Its extinction angle $c : n\gamma = 38$ deg. to 45 deg.

Zircon is an accessory mineral. It is brown, possesses high relief, high interference colours and uniaxial positive character. Its surface appears rough and traversed by many cracks. It shows straight extinction against the crystallographic edges. *Titanite* is another common accessory mineral.

The rock appears to be the contact metamorphic product of a bank occurring in the gneiss and originally consisting of siliceous limestone. As such, it must be included in Group IX of Grubenmann's classification (Katazone).

II. Eruptive Gneiss.

(a) *The Granulite.*

It is a flesh-red, holocrystalline, compact, medium-grained rock. The granulose structure is accompanied by an indistinct banded texture, produced by the alternation of layers with different sized grains. In the hand-specimen the constituent minerals are recognised to be flesh-red felspar, quartz, biotite and muscovite, tourmaline being also occasionally present. The biotite occurs here in very minute scales, and its lamellar character which controls the schistosity of the gneisses and schists had no influence on the texture.

The mineral constituents of the rock with its somewhat aplitic character and its granular structure define it as a granulite. Similar rocks have also been observed by Suter[1] in the Murgtal. Schwenkel's definition of granulite is somewhat different. It may be ıesumed as follows :—

"Unter Granuliten versteht man im Schwarzwald saure Gesteine, die der Formation des Eruptivgneisses angehören und in der Regel keinen Biotit, aber Granat führen."

The rock is frequently traversed by zones (*veins*), which are conspicuous by their white colour. They consist of strongly decomposed rocks, that have the appearance of being formed as a result of differential movement. Veins of pure quartz are also met with.

Under the microscope, the rock is found to consist of sutured aggregates of quartz, felspar and biotite, the latter usually decomposed and changed into sericite. The whole of the quartz in the rock has been crushed and granulated. It now forms the finely pulverized matrix in which the felspars are embedded, and, where the latter have been fractured, this matrix also enters into the resulting cracks. The quartz and felspar show strain shadows and the structure may be said to be typically grano-blastic to porphyroclastic. The biotites—and to a certain extent the felspar also—being naturally more flexible, have usually yielded to the strain by bending or chemical metamorphism, rather than by complete disintegration.

Tourmaline is the most common accessory mineral of the rock. At certain places it is so much enriched that it may there be considered a chief constituent.

Chlorite, muscovite, garnet, andalusite, cordierite, pennine, etc., are the other accessories. At many places the muscovite occurs in veins, which may mark the channels through which the volatile components passed.

The *felspars* present in the rock are of the following varieties :—

Orthoclase, perthitic orthoclase, microcline with cross-hatching and *plagioclase* with the following characteristics :—

It is polysynthetically twinned with fine twinning lamellæ. Its maximum extinction angle about the zone [010] = – 14 deg., its refractive index is lower than that of quartz, and it is optically positive, thus being recognisable as *albite-oligoclase*. Sometimes the plagioclase is zoned. Grains of hæmatite have occasionally separated from decomposed individuals and call forth the flesh-red colour, which may be found in plagioclase as well as in orthoclase. The hæmatite grains are partly centrally heaped and partly disseminated along the cleavage lines in the felspar crystals.

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[1] Suter, Dr. H. Diss. Zurich, 1924.

Quartz.—All the quartz with the exception of some of that found enclosed in felspar is crushed. It is full of gas bubbles. Sometimes it unites with orthoclase to form a graphic structure.

The *biotite* is of the greenish brown pleochroic lepidomelane variety. The absorption colours are:—

$$\underset{\text{Deep greenish brown}}{n\gamma = n\beta} \quad > \quad \underset{\text{Light brown}}{n\alpha}$$

In many cases it has been decomposed, the decomposition products being chlorite, limonite, muscovite and leucoxene.

Tourmaline.—Typically pleochroic and apparently of the Fe-Mg variety. The pleochroic colours vary between :—

Bluish green to green,
occasionally Brown to green,
usually Deep brown to brown.

$$0 > E$$

It sometimes shows a zonal development, and has in many cases been decomposed into muscovite, etc.

Fresh tourmalines are very frequently met with in the above-mentioned vein, forming zones in which the individuals show an arrangement somewhat resembling strings of beads. We are thus led to suppose that these portions correspond to original clefts in the rock along which differential movements could take place. At the same time they offered a passage for the volatile components which decomposed the rock (greisen-formation) and deposited the tourmaline.

The presence of tourmaline is particularly interesting in view of the fact stated on page 14 that no pneumatolytic action later than the middle Triasic (Muschelkalk) can be traced in the Black Forest. The fact that the differential movements were accompanied by the passage of volatile agents (formation of tourmaline by pneumatolysis) dates them as Hercynian and excludes them from the later movements of the Tertiary period.

Like the dislocation zones, the natural cleavage planes of the rock have also been invaded by solutions containing gaseous fluxes which formed tourmaline, etc. The surface of the cleavage planes appears rusted. This could naturally be the case if a solution containing iron had circulated through them. Just under the surface, for about a millimetre or two, the rock is black and has a fine-grained structure and compact texture. The general appearance suggests a crushing of the rock, and a concentration of biotite parallel to the surface. The microscopical examination shows, however, that the black colour is due to strong concentration of minute tourmaline individuals, so that one is forced to suppose that the cleavage planes have also offered an outlet for the volatile components.

Muscovite is quite common in the rock. It is both a primary mineral, being of pneumatolytic origin like tourmaline, and as sericite a secondary one formed out of orthoclase and biotite.

Andalusite is an interesting accessory mineral of the rock. It is slightly pleochroic. The pleochroic colours vary between pink to colourless. It is very often found side by side with tourmaline, but stray prisms also occur. It has undergone resorption in the edges, sometimes with the development of scales of muscovite. It possesses high relief, rough but shining surface, low interference colour ($\gamma - \alpha$ = about 0.011) and biaxial negative character. It shows straight extinction along the crystal edges, but symmetrical extinction along the well-developed prismatic (110) cleavage lines.

Cordierite is another interesting accessory mineral. It is very rarely found fresh. Very probably the aggregates of pennine and limonite, which occur frequently in the rock, are the remains of decomposed cordierite individuals.

Hornblende is a common accessory mineral. It occurs in green, pleochroic, disseminated patches, with prominent cleavage lines and high interference colours.

Its pleochroic colours are as follows :—

$n\gamma = n\beta$	$>$	$n\alpha$
Olive green		Light green to colourless.

Apatite occurs in needles and grains.

Garnet is a rare accessory mineral of the rock. No garnet was observed in any of my sections. I found garnets in a section lent by Prof. Niggli.

Haematite has often been found separated from felspars. It also occurs as a decomposition product of biotite.

The mineral constituents of other granulite occurrences in the area correspond closely to the above, and the structure of the rock from the outcrops at Vogelbach and Schurlebach is identical with that of Albbruck. Somewhat different structure is shown by the rock outcropping at Mühlebach. This occurrence seems to be an apophysis of the main Albbruck granulite or of its eastern continuation. Being smaller in size, the apophysis underwent different conditions of crystallization, which are reflected in the fine structure shown by the hand-specimen. Under the microscope the structure is typically granoblastic. Its contents in *microcline* is somewhat greater than that of the Albbruck granulite.

In addition to microcline the rock contains the following components :—

Quartz with abundant gas bubbles, *orthoclase*, *plagioclase*, of the composition of albite-oligoclase (Ab_{90} An_{10}), much corroded and limonitised *biotite*, *zircon*, etc.

A chemical analysis of the rock, rich in tourmaline, collected from the Government quarry at Albbruck, gives the following results :—

Granulite.

Analysed by :—S. K. Ray.

Comp.	Weight per cent.	Molecular proportions.
SiO_2	73.61	1,227
TiO_2	Nil	Nil
P_2O_5	0.20	1
Al_2O_3	14.82	145
Fe_2O_3	0.78	5
FeO	0.37	6
MgO	0.64	16
MnO	0.02	—
CaO	0.43	7
Na_2O	2.97	48
K_2O	5.46	58
$+H_2O$	0.31	—
$-H_2O$	0.07	—
B_2O_3	0.71	26
Total	100.39	

Molecular proportions according to Niggli.	
si	425
al	50
fm	11
c	2
alk	37
k	0.58
mg	0.50
ti	0.0
p	0.17
$\frac{c}{fm}$	0.18
si′	+ 177

Section I.

Specific gravity : 2.64.

Magmatype : Aplite-granitic.

Norm. of the rock (granulite) :

Mineral.	Weight per cent.
Apatite	0.33
Orthoclase	32.24
Albite	25.15
Anorthite	1.12
Magnetite	1.16
Corundum	3.46
Hypersthene	1.73
Quartz	33.96

III. The Injection Veins.

On page 10 I have said that the magma which formed the granulite of Albbruck has intruded into the gneisses. The bands in the injection gneisses possess the same flesh-red colour as the granulite of Albbruck, and may, therefore, be taken to have the same composition as the granulite.

The microscopical characteristics of a section of one of these veins, as given below, confirm this supposition.

The vein examined was separated from the injection gneisses about 200 metres north of the granulite outcrop Albbruck and was about 5 cm. thick. In the hand-specimen the rock (the vein) has the same flesh-red colour and almost the same texture as the granulite of Albbruck. The mica gneisses above and below the vein are seen to be a little resorbed by it. The chief vein has also sent smaller and finer veins into the bedding planes of the gneisses.

The fact that the vein possesses somewhat finer grained structure than the granulite of Albbruck can easily be deduced from a comparison of the genesis of the two rocks. The rapid cooling resulting from an intrusion into the bedding planes of a relatively cold rock naturally produced a finer crystallisation than would occur in the granulite laccolith of Albbruck, which, being larger, would also cool much more slowly.

Under the microscope the rock possesses a typical "augen-" structure. Crystals (ocelli) of felspar, showing a more or less subparallel arrangement of their longer axes, are found approximately to follow the direction of the stream lines of a streaky matrix consisting of sutured quartz and scales of muscovite. This directive texture is produced by the flowage of the magma before its crystallisation was completed. Two generations of crystallisation are clearly in evidence. The larger felspar individuals correspond to the more deep seated (intratelluric) and slower phase of crystallisation of the magma. They were at a later period raised and with the still liquid magma injected into the relatively cold gneiss rocks. The resulting rather abrupt decrease in temperature accelerated the rate of cooling, the result being the small individuals of quartz and mica in the ground mass.

The mineral composition of the rock is exactly the same as in the granulite. In the main mass we find porphyroblastic ocelli of *orthoclase*, *albite*, *microcline*, and occasionally of *biotite*. Sutured quartz and muscovite are found in the matrix. *Tourmaline* also occurs.

In the contact zone with mica gneiss, biotite is occasionally met with. It is to a large extent, however, decomposed into *chlorite* and *leucoxene*, which form the matrix in which the ocelli of felspars are embedded.

Prisms of *andalusite* are also common in the contact zone.

IV. Injection Gneisses.

This is a further type of gneiss frequently met with. It is characterised by a banded appearance called forth by alternation of dark layers, consisting megascopically of biotite, and flesh-coloured layers, in which quartz and felspar may be recognised. The bands are usually plane lamellæ, gently undulating with continuous foliation, though the quartz felspar mixture occasionally assumes the form of oval patches in the biotite, thus giving rise to a locally lenticular or phacoidal texture, with interrupted foliation.

Under the microscope the rock is found to consist of 45% quartz, 20% orthoclase and perthite, 13% biotite, 7% microcline, and 5% plagioclase.

As accessory minerals are found rutile, garnet, muscovite, apatite, zircon and magnetite.

The components are all equally dimensioned, but possess irregular margins. Neither the quartz, which usually has jagged outlines, nor any of the other constituent minerals show good crystal forms. The structure is thus granoblastic. Many of the grains possess elongated shape and an approximately parallel arrangement. This gives rise to a faintly indicated linear texture. All the components show undulose extinction.

Quartz is the most abundant constituent of the rock. Most of the grains possess inclusions of gas bubbles, but there are many —especially among those contained in felspar—which are perfectly transparent.

Felspars.

Perthite is the commonest of all the felspars. It usually occurs in fairly big patches, and has partly undergone decomposition.

Microcline possesses the usual cross-hatching, and is often met with in the sections.

Plagioclase possesses polysynthetic twinning lamellæ, and sometimes has a zonal structure. Its refractive index is lower than that of quartz, it is optically positive and shows an extinction angle of + 20°, against the cleavage parallel to (001), on a section about vertical to $n\gamma$. It is therefore albite.

Biotite.—This is the only important coloured constituent of the rock. It is brown and pleochroic, being of the lepidomelane type.

Rutile needles are sometimes found in the biotite.

Garnet occurs in isotropic grains with high relief, and is traversed by innumerable lines of fracture. Sometimes it has suffered resorption in the margin.

Sericite occurs in scaly clusters, or in lamellæ as decomposition product of felspar.

Summary.

The preceding observations have shown that the chief characteristics of the Black Forest gneisses may be resumed as follows :—

(1) They are partly of sedimentary origin (Rench gneiss) and partly of igneous (ortho-) derivation (Schapbach gneiss).

(2) Abundant proof of aplitic injection is widely met with.

(3) Muscovite, tourmaline and microcline occur frequently, and indicate pneumatolytic activity.

(4) Conspicuous among the constituent minerals are quartz, orthoclase, microcline, plagioclase (albite—oligoclase—andesine), biotite, hornblende, andalusite, garnet, cordierite, and sillimanite. The last are sometimes so important as to give rise to typical cordierite sillimanite gneiss.

It may be mentioned at this point that Sauer considered the gneisses of Erstfeld (Aar-massif, Switzerland) and of the S. Black Forest to be identical.

It is interesting to note that U. Grubenmann ("Uber einige tiefe Gneise aus den Schweizeralpen," p. 622 [1]) in his summary of the Erstfeld gneisses lays stress on exactly the same mineral composition, pneumatolytic activities, etc., as have been stated above.

The marked resemblances of the rock complexes may be taken to indicate a similar cycle of metamorphism during the Hercynian upheaval.

B. THE PRE-GRANITIC BASIC INTRUSIONS.

These include, as has already been stated on pp. 8, 13, the amphibolites and anorthosites of the Tiefenstein area.

Amphibolites are widely distributed all over the Southern Black Forest, usually accompanied by gneiss. They have been studied in detail by Weinschenk in Todtmoos,[2] by Erdmannsdörffer in the Wehratal[1] and by my friend Suter[2] in Laufenburg. Philipp reports them from the Wiesental in connection with the gabbroid rocks of the locality.[3] Further references are found in the works of Kloos,[4] Deecke[5] and many other German geologists.

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[1] Extrait du Compte Rendu du XI^e Congrès Géologique International, p. 622.

[2] Weinschenk. Ni-Magnetkieslagerstätten im Bezirk St. Blasien im Süd-Schwarzwald. Zt. f. prakt. Geol., 1907. März.

Anorthosites, on the other hand, have hitherto not been reported from this part of the Southern Black Forest, and these rocks are, on the whole, nowhere very common in Germany. Philipp, in the introduction to his chapter on anorthosites in the Wiesental, says that with the exception of certain solitary labradorite blocks,[6] found near Rosswein, Saxony, anorthosite rocks were reported from no other locality in Germany until his time (1909). Philipp made no chemical analyses of the anorthosites of the Wiesental; he himself admits that the one he refers to in his work is faulty.[7]

I. Amphibolites.

Like many other massifs of acid rock,[8] the Albtal massif is accompanied by marginal basic intrusions which consist in the Tiefenstein area of amphibolites and anorthosites in the southern margin (see profile II), and of amphibolites by the Albtal road about 1½ km. south of Niedermühle and at Ibach, opposite the saw-mills, in the northern margin.

Megascopically, the rocks have a dark green to yellowish black colour, are usually schistose, but sometimes massive in texture and possess structures varying between very coarse-grained gabbroid to fine-grained lamprophyric. They are composed in general of alternate layers of hornblende and felspar.

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[1] Erdmannsdörffer. Geol. Petrogr: Untersuchungen in Wehratal, Mittleg. Grossh. Bad. Geol. La.A.Bd. IV, 1901.

[2] Suter. Diss., Zurich, 1924.

[3] Philipp. Stud. aus dem Gebiete der Granite u. umgewandelten Gabbros des Wiesentales. Sond. aus der Mittlg. Grossh. Bad. Geol. L.A. Bd. VI Heft 1, 1910.

[4] Kloos. Studien im Granitgebiet des S. Schwarzwalds, N.J. f. Min. B. Bd. III, 1884.

[5] Deecke. Geol. von Baden, lit. 12.

[6] Probably enclaves. S.K.R.

[7] Philipp. The same as above, p. 57.

[8] Similar marginal occurrences of amphibolites and basic rocks are reported from the following localities:—

- *a.* Scheumann. Zeitschrift für Kristallographie, Bd. 57, p. 582. "Peridotite, pyroxenite, gabbro and anorthosite, etc., are found in the marginal region of the granulite massif of Saxony."
- *b.* Hatch. Textbook of Petrography, London, 1914, p. 374. "Dolerite is found in abundance in the margin of Dartmoor granite."
- *c.* Teall. Quart. Journ. Geol. Soc. Surv. Vol. LXVII, 1892, p. 104. Reports that Norites, etc., occur in association with the granite massifs of the South-West Highlands. Lit. 65.

The proportion of the hornblende to felspar is somewhat variable, and the colour of the rocks varies correspondingly.

The hornblende is easily recognised. It forms crystals of yellowish black colour and vitreous to pearly lustre on its perfect cleavage faces. The felspars are white and possess no lustre or good cleavage. Occasionally fresh pyrites is found along the natural cleavage planes of the rocks.

The weathered surface of the rocks has a greyish green, earthy appearance.

Under the microscope the rock is found to consist of fresh green hornblende and saussuritised felspars as the chief constituents. The felspars form about 40 per cent. and the hornblendes about 60 per cent. of the rock. The accessory minerals in the rock are quartz, biotite, chlorite, leucoxene, epidote, apatite, muscovite, pyrites, limonite and actinolite. Although the texture of the rock appears practically massive, the linear foliations already mentioned again assert themselves by the fact that the hornblende individuals mostly have their c' axis in one plane. All the constituents show to a marked degree, a lack of idiomorphic development. The chief constituents, the hornblendes and the plagioclase, are usually found intruding one into the other. Therefore the structure is granular with tendency to granoblastic.

Characters of the Individual Minerals.

Plagioclase is usually decomposed, but occasionally waterclear, fresh individuals are observed. As a rule the individuals are twinned with broad twin lamellæ, but untwinned individuals also occur. It is optically +, the extinction angle on the section about vertical to $n\gamma$ against (010) varies between 5 deg. to 18 deg., but usually it is about 12 deg., and the maximum extinction angle in [010] is 38 deg. These are the characteristics of andesine—labradorite. Some of the individuals, especially when zoned, show negative optical properties. They appear to have the composition of an acid Bytownite.

Hornblende is the most abundant constituent of the rock. It is green and pleochroic. The pleochroic colours being :—

$n\gamma$	$>$	$n\beta$	$>$	$n\alpha$
Bluish green		Yellowish green		Light yellow

Ext. angle on (010) against $n\gamma$ = about 20½°

Usually the mineral occurs with bad crystal outlines, or in patches consisting of an individual torn into pieces, but in some of the sections hornblende with lozenge-shaped outlines is observed.

The angle between the prism faces was measured and found to be about 125¼ deg. and 54¾ deg. The prism faces (110) are better developed than the pinacoids (010), hence the lozenge-shaped form. There are many instances of biotitisation and chloritisation of the hornblende in the sections. Biotites are more common in those sections where the pleochroic colours of the hornblende have a deeper tinge of blue. The blue colour of the hornblende may be taken to correspond to an increased content in alkali aluminous silicate.[1] See Fig. 3.

Small veins of injected pegmatite can distinctly be traced and the blue colour of the hornblende, as well as the biotitisation, are seen to be closely bound to the veins. We may therefore suppose that an alkalisation, originating from the pegmatite, has taken place.

Quartz occurs very rarely in water-clear grains, which are usually biaxial, but sometimes uniaxial. The grains are usually embedded among the decomposition products and are surrounded by kaoline, etc. (Saussuritisation).

Chlorite.—In many instances, the hornblende has been changed into green, slightly pleochroic chlorite (pennine), possessing anomalous interference colours. Transition between hornblende and chlorite has been observed.

Leucoxene.—This occurs side by side with chlorite as a decomposition product of hornblende. In transmitted light it resembles grey, almost opaque spots, which are quite white in the reflected light. Leucoxene is formed from TiO_2, which occurs in hornblende, replacing a part of its SiO_2 at high temperature and afterwards separating from it when the temperature fell.[2]

Biotite.—This forms one of the most interesting accessory minerals of the rock. Profuse biotitisation is observed only in those sections where the hornblende has been alkalised (Fig. 3). It is pleochroic. The pleochroic colours vary between

$n\gamma = n\beta$	$>$	$n\alpha$
Light brown		Colourless

Zoisite occurs in greenish, almost colourless prisms. The surface is rough and is full of grey spots. Possesses good crystalline outlines and cleavage lines. Interference colour low. This is a decomposition product of plagioclase or probably of both hornblende and plagioclase.

Muscovite is found near the pegmatite veins cutting through the amphibolites. Individuals sometimes occur with well-formed six-sided outline.

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[1] Niggli. Lehrbuch der Mineralogie, Berlin, 1920. (The norm of the rock (see p. 33) also shows presence of nepheline molecules).

[2] Niggli. Lehrbuch der Mineralogie, p. 395, 1920, Berlin.

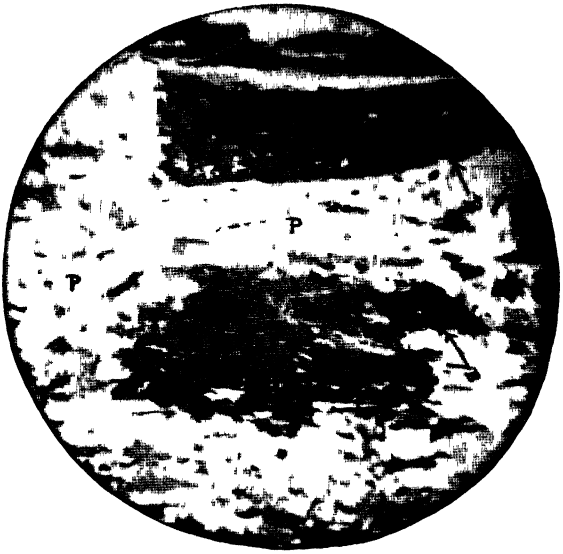

Fig. 3.

Hornblende alkalised and partly changed into biotite by a pegmatite vein

H Hornblende. B Biotite. P—Pegmatite

Magnification 20 ×. (Plane polarised light).

Pyrites.—A common accessory in the rock. Sometimes it is limonitised.

Actinolite.—This is an interesting recrystallization-product of hornblende, occurring in light-green, slightly pleochroic crystals at the ends of the many hornblende prisms.

When the amphibolite is decomposed, it loses its colour and lustre and assumes the appearance of a mass of fine-grained, earthy rock. Under the microscope this altered amphibolite is found to consist of limonite, chlorite and scales of paragonite.

A chemical analysis of the rock gives the following result :—

Amphibolite.

Analysed by :—S. K. Ray.

Comp.	Weight per cent.	Molecular proportions.
SiO_2	48.60	810
TiO_2	0.27	3
P_2O_5	0.39	3
Al_2O_3	17.94	175
Fe_2O_3	2.08	13
FeO	8.15	113
MnO	0.45	7
MgO	6.66	166
CaO	9.16	164
Na_2O	2.91	47
K_2O	2.10	22
$+H_2O$	1.58	—
$-H_2O$	0.03	—
Total	100.32	

Molecular proportions according to Niggli.	
si	112
al	24.0
fm	43.5
c	23.00
alk	9.5
k	0.32
mg	0.53
p	0.40
ti	0.40
c/fm	0.52
si′	− 26

Specific gravity :—2.94

Magma type :—Gabbrodioritic.

Norm of the rock (Amphibolite) :

Mineral.	Weight per cent.
Apatite	1.00
Rutile	0.24
Orthoclase	12.23
Albite	21.48
Anorthite	29.47
Nepheline	1.70
Magnetite	3.01
Diopside	12.14
Olivine	18.56

According to Grubenmann's classification, this rock must be included in Group IV, and no doubt belongs to the Meso-Zone.[1]

According to this author amphibolites may be derived from both sedimentary and igneous rocks. It is, therefore, interesting to note that the molecular proportions of the analysis quoted above are in almost complete agreement with the values quoted by Niggli[2] as typical for rocks of the Gabbrodioritic magma.

Molecular proportions :—

	si	al	fm	c	alk	k	mg	c/fm
(1) Amphibolite	112	24.3	43.3	22.8	9.6	0.32	0.53	0.5
(2) Gabbrodiorite	135	24.0	43.5	22.0	10.5	0.28	0.50	0.57

The ortho derivation is, therefore, very probable, and it is further confirmed by the mode of occurrence as previously mentioned (see pp. 8 and 30, and profile II).

At a later period the amphibolites have been traversed by innumerable dykes and veins of felspar and quartz, or both together with biotite, the latter mixture possessing the appearance of a fine-grained granite, or sometimes of a porphyritic granite of exactly the same structure as the Albtal granite. *Pegmatitic dykes* of quartz and felspar, sometimes with the development of graphic (eutectic) structure are the commonest of all. These veins are usually from 3 to 5 inches in thickness. They usually cut the amphibolite masses in a vertical direction, but occasionally they are injected into the bedding planes of the amphibolites and swell up into irregular lenticular masses, about a foot across, with different structures (varying between fine and coarse-grained) within the same mass.

In many places one system of pegmatite dykes is found to have been cut through by another system of the same rock. This shows that there have been several phases of extrusion.

The pegmatite and granite veins are not metamorphosed. I believe they derive from the same magma basin as the pegmatites of Laufenburg.[3] Pegmatite veins have not yet been observed within the Albtal granite, and they are very rare in the gneiss of the locality. Probably the contact between granite and amphibolite offered a zone of reduced resistance, and was thus predestined to serve as an outlet for the pent-up pegmatitic solution.

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[1] Grubenmann: Kristalline Schiefer, Berlin, 1910.

[2] Niggli: Lehrbuch. See lit. 38.

[3] Suter. Diss. Zürich, 1924.

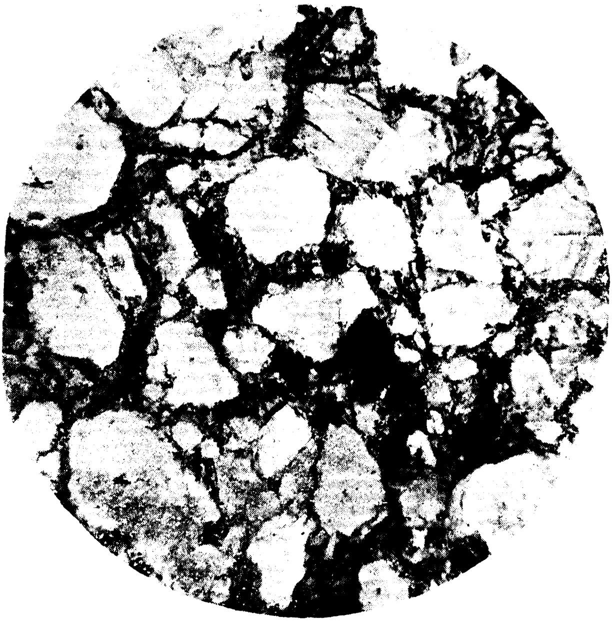

Fig. 4.

Amphibolite with honey-combed appearance.
Magnification: 24 ×. Plane polarised light.

The amphibolites have, in the parts adjoining the granite and pegmatite veins, been resorbed by the latter and the hornblende has been changed to chlorite. In some cases the re-crystallized rock has assumed a peculiar honeycombed appearance with cells of plagioclase walled in by chlorite spotted with leucoxene (see fig. 4).

The microscopic character of the pegmatites shew them to be ordinary mica pegmatite.

The felspars of the pegmatite veins.—Two kinds of felspathic pegmatite veins are found in the amphibolites. One is lilac-red and the other is almost milk-white. The chief accessory mineral in both cases is quartz, which, however, is only present in subordinate amount.

The felspar in the red veins possesses low refractive index. shows straight extinction against the cleavage lines (010) on a section cut parallel to the face (001). On the section (010) the extinction angle is about 6^0. Therefore it is orthoclase. At many places it is decomposed, and scales of sericite have been formed.

The white veins consist of untwinned plagioclase felspars. They are optically positive, possess a refractive index higher than that of quartz ; they have good cleavage lines, and their extinction angle on the face $(001) = -1^0$. These properties define the felspars to be andesine-labradorite, *i.e.*, about $An_{40}\ Ab_{60}$. Most of the felspars in the amphibolites are of a similar composition. In many instances the plagioclase has been decomposed.

There are also veins :—

(*a*) Composed of both the types of felspars.
(*b*) Composed of quartz alone, and
(*c*) Composed of granite.

The granitic veins in the amphibolite are characterized by the presence of garnets. This occurrence is unique as regards the igneous rocks of the Tiefenstein area.

The quartz veins sometimes contain big druses of quartz. The crystals are bounded by prisms and two kinds of rhombohedrons. One individual was found to end with a slanting baselike face, the formation of which must be due to resistance in the direction of *c* axis during the growth of the crystal.

Immediately adjacent to Humbert's house, Tiefenstein, the amphibolite is developed in a peculiarly fine-grained variety. In the hand-specimen it is quite compact and massive, and possesses conchoidal fracture. Its colour is yellowish black, and none of its component minerals can be distinguished megascopically.

Under the microscope it shows a typical brecciform structure, and consists of angular fragments of grass-green hornblende and decomposed plagioclase.

The plagioclase is twinned both according to the Carlsbad and albite laws of twinning. Its extinction angle on (001) $= +\frac{1}{2}°$; another section vertical to $n\gamma$ shows an extinction angle $= -7°$. These are the characteristics for andesine with composition about $Ab_{63}\,An_{37}$.

The hornblende found in the rock possesses characters identical with those mentioned in connection with the hornblende of the amphibolites.

II. Hornblende-Anorthosite.

Megascopical characters.—In its purest form, that is in uninjected and unaltered form, the rock has a bluish-white colour and a coarse-grained massive texture. The main constituent minerals are yellowish-black or dark green hornblende possessing good lustre on the cleavage faces, and bluish-white plagioclase whose polysynthetic twinning lamellæ can be observed quite clearly with a lense.

When decomposed the anorthosite has a rusty appearance similar to that of weathered granite. The hornblende is altogether decomposed, and the iron oxide set free, is the cause of the colouration.

Under the microscope the rock is found to consist of fresh grass-green hornblende and basic plagioclase as the chief constituents. The accessories are quartz, chlorite, biotite, zoisite, muscovite and pyrites.

The felspars are partly decomposed but occur in crystals of various dimensions. Sometimes one individual occupies the whole field of observation, although smaller individuals also occur. All of them possess broad twinning lamellæ and more or less good crystal margins, and are arranged in a quite irregular manner. The hornblende, on the other hand, which does not exceed about 10 to 15% of the whole volume, occurs in very irregular patches consisting of several individuals without any crystallographic outline at all.

The structure of the rock may therefore be called typical gabbroid (hypidiomorphic granular) or sometimes even porphyroid.

At certain places the rock is traversed by minute veins, which consist almost wholly of muscovite, with occasional biotite. The muscovite may be considered as of pegmatitic or hydrothermal nature. The veins are perhaps the furthest continuations of those met with in the amphibolite.

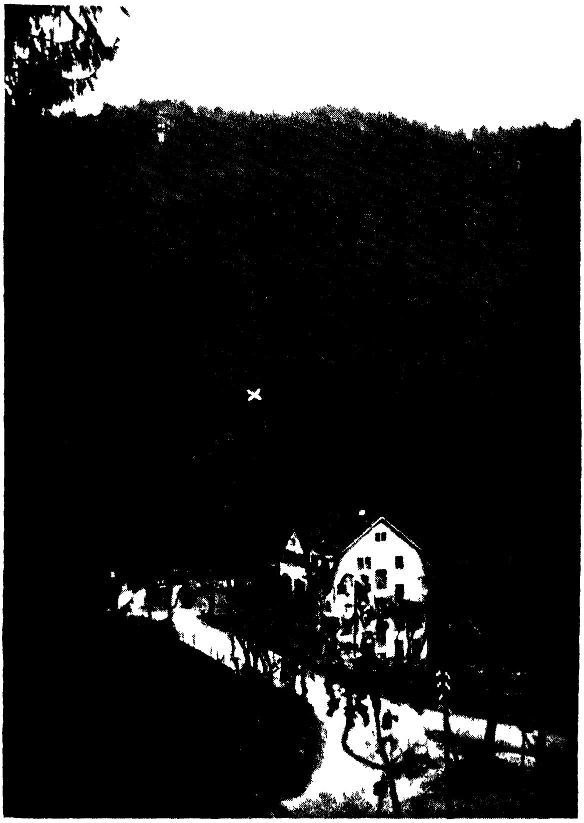

Fig. 5.

Anorthosite outcrop (X), Tiefenstein.
(See pages 13 and 36).

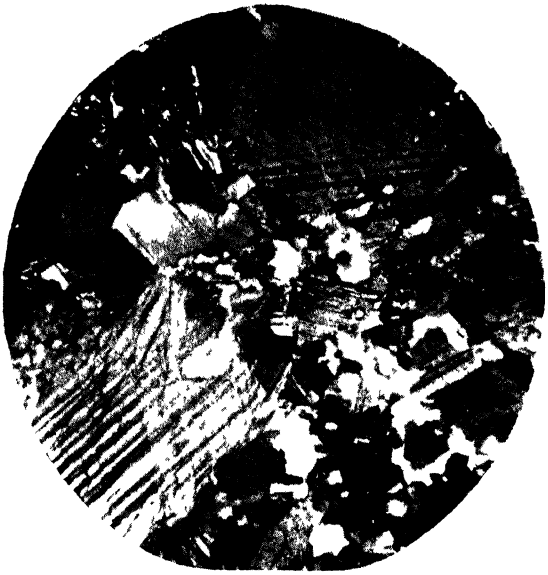

Fig. 6.
Anorthosite. Magnification: 28 ×

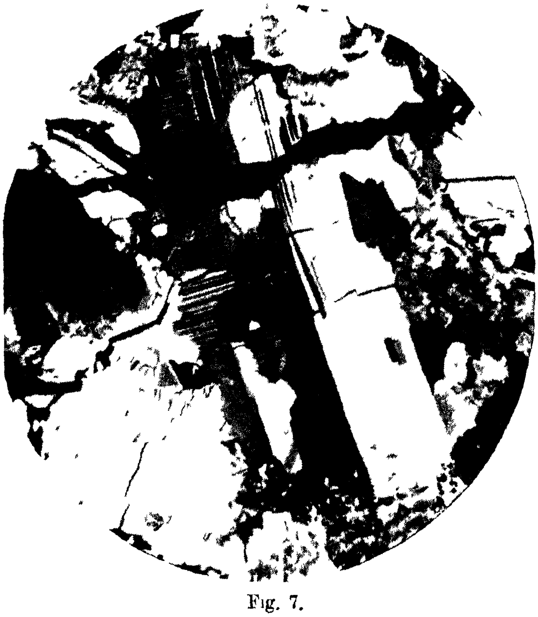

Fig. 7.
The plagioclase (Ab_{30} An_{70}) of anorthosite with cross-hatching.
Magnification: 28 × Nichols crossed.

Description of the Constituent Minerals.

Plagioclase.—Usually appears as stout prisms or elongated rectangles, or sometimes in square sections possessing good cleavage lines but no ideal crystallographic edges. Most of them are highly twinned according to the albite law and usually according to the pericline law. Sometimes half of one individual is heavily twinned according to the albite and pericline laws and the whole is twinned again according to Carlsbad law. The other half may possess only the albite type of polysynthetic twinning lamellæ. Sometimes the twinning lamellæ are so prominent that they can already be seen in plane polarized light. This complicated system of twinning sometimes gives rise to cross-hatching on the felspars (see figs. 6 and 7). In rare cases we, however, come across individuals that are not twinned at all. Zonal structure is occasionally also met with.

The refractive index of the plagioclase is usually higher than that of quartz, but sometimes it is equal to quartz. The extinction angle on the face (100), about vertical to $n\gamma$ against (010), varies between $-36°$ and $-40°$. On sections parallel to (001) the ext. angle is $-19\frac{1}{2}°$. Most of the individuals are optically +, but negative plagioclase rich in Ca is also occasionally to be met with. It appears to have the composition of $An_{75}Ab_{25}$ to $An_{70}Ab_{30}$ *

Hornblende.—The green hornblende possesses the following pleochroic colours :—

$n\gamma$	$=$	$n\beta$	$>$	$n\alpha$
Olive green.		Olive green.		Light green.

Some of the individuals possess a deep tinge of blue in the margins. This may be due to alkalisation, as has been referred to on p. 32. The optical character is negative and the ext. angle on the face (010) against $n\gamma$ is 21°.

Some of the individuals have been so far converted into chlorite that only a central core of unaltered hornblende remains. The pleochroism of the periphery—*i.e.*, of the chlorite—is sometimes scarcely distinguishable from that of the hornblende. The interference colours, however, prevent any confusion.

The above data correspond closely with those found by other students of Southern Black Forest geology.

* On studying these felspars by Fedorow's method, Dr. R. L. Parker found cases of the Manebach type of twinning. The composition, according to Dr. Parker is An_{69} Ab_{31}.

(1) Erdmannsdörffer reports[1] that the hornblende in the amphibolites of Wehratal possesses green to bluish-green pleochroic colours. And the hornblende found in the syenites of the Wehratal[2] possesses the following pleochroic tints :—

$n\gamma$	$>$	$n\beta$	$>$	$n\alpha$
Olive green.		Green.		Colourless to light green.

Their extinction angle $c : n\gamma = 14^\circ - 15^\circ$.

(2) Philipp[3] informs us that the hornblende found in the olivine-gabbro rocks of the Wiesental has an extinction angle $= 20^\circ$:

$n\gamma$	$>$	$n\beta$	$>$	$n\alpha$
Bluish-green to light-green.		Yellowish-green.		Colourless.

(3) The hornblende in the amphibolites of the Tiefenstein area[4] possesses the following characteristics :—

$n\gamma$	$>$	$n\beta$	$>$	$n\alpha$
Bluish-green.		Yellowish-green.		Light yellow.

Ext. angle on (010) = about $20\frac{1}{2}^\circ$.

Quartz occurs in small water-clear drops or in patches which often show signs of strong marginal resorption. All the individuals more closely examined showed biaxial + character. This proves that the rock has been subjected to pressure after the quartz was formed. The latter includes many gas bubbles and liquid drops.

Chlorite is a common decomposition product of hornblende, to which a gradual transition can in many cases be traced. It is green, in many cases fairly pleochroic, occurs usually as scales, optically biaxial, positive and possesses very low interference colours.

Biotite is another interesting accessory of the rock. It occurs usually side by side with chlorite and results from the addition of potassium to the rock by the pegmatite solutions.

Leucoxene.—This mineral occurs along with chlorite, as another decomposition product of hornblende, in grey, almost opaque patches, which appear white in the reflected light.

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[1] Erdmannsdörffer : p. 153 & 160. See lit. 15.
[2] Ibid., lit. 15, p. 160.
[3] Philipp, p. 46. lit. 48.
[4] *Vide ante.*

Zoisite occurs in colourless prisms with good cleavage lines. It possesses a rough surface, straight extinction and abnormal greyish-blue to greenish-blue interference colours. Optically the mineral is biaxial and positive. It is usually surrounded by patches of leucoxene.

Pennine.—As has been stated above, the anorthosite is at certain places injected by veins of pegmatite. Under the microscope these veins are found to consist of muscovite and sericite with accessory biotite. Sometimes these veins have given rise to druses in the rock. The crystals of the druses are green and almost non-pleochroic. Optically they are biaxial positive, but their character in the chief zone is negative, $\gamma - \alpha$ = about 0.007—and they show an extinction angle = 2 to $3\frac{1}{2}°$ against the cleavage lines. By these characteristics they may be determined as pennine with a slight tendency towards chlinochlor.

Pyrites, *apatite* and *garnet*, etc., are the other accessories of minor importance.

For the geological position of the rock see page 13.

A chemical analysis of the anorthosite gives the following result :—

HORNBLENDE - ANORTHOSITE.

ANALYSED BY S. K. RAY.

Comp.	Weight per cent.	Molecular proportions.
SiO_2	46.73	778
TiO_2	0.54	7
P_2O_5	0.03	—
Al_2O_3	29.70	294
Fe_2O_3	0.05	1
FeO	2.41	33
MnO	0.05	—
MgO	0.30	8
CaO	14.55	260
Na_2O	2.09	34
K_2O	1.75	18
$+H_2O$	1.55	—
$-H_2O$	0.18	—
Total	99.93	

Molecular proportions according to Niggli.	
si	121
al	45.5
fm	6.5
c	40.0
alk	8.0
k	0.35
mg	0.19
ti	1.10
p	
c/fm	6.2
si′	− 19

Section IX.

Specific gravity .. .. 2.74.

Magma type .. Labradorfelsitic—Anorthositic.

Norm of the Hornblende - anorthosite :

Mineral	Weight per cent.
Rutile	0.56
Orthoclase	10.00
Albite	9.43
Nepheline	4.54
Anorthite	67.27
Magnetite	0.23
Diopside	4.33
Olivine	2.11
H_2O	1.73
Total	100.21

The chemical analysis of the rock corresponds to the following anorthosite rock :—

	si	al	fm	c	alk	section
Anorthosite Beaver Bay ([1])	118	46.5	5.5	41.5	6.5	IX
Anorthosite Tiefenstein	121	45.5	6.5	40.0	8.0	IX

The following physico-chemical consideration will give an insight into the genetic conditions of these two rocks.

Both amphibolite and anorthosite may be regarded as derivatives of a melt whose chief components may be expressed as albite, anorthite, and diopside. This system has been examined by N. L. Bowen, who gives the appended diagram (fig. 8).

We see that melts having a composition richer in diopside than the composition of the eutectic line (EF) must first separate

[1] Niggli. Gesteins & Mineralprovinzen, Bd.I, p. 140. (Berlin, 1923.)

diopside, and later, when the eutectic line is reached, a mixture of diopside with plagioclase of constantly varying composition.

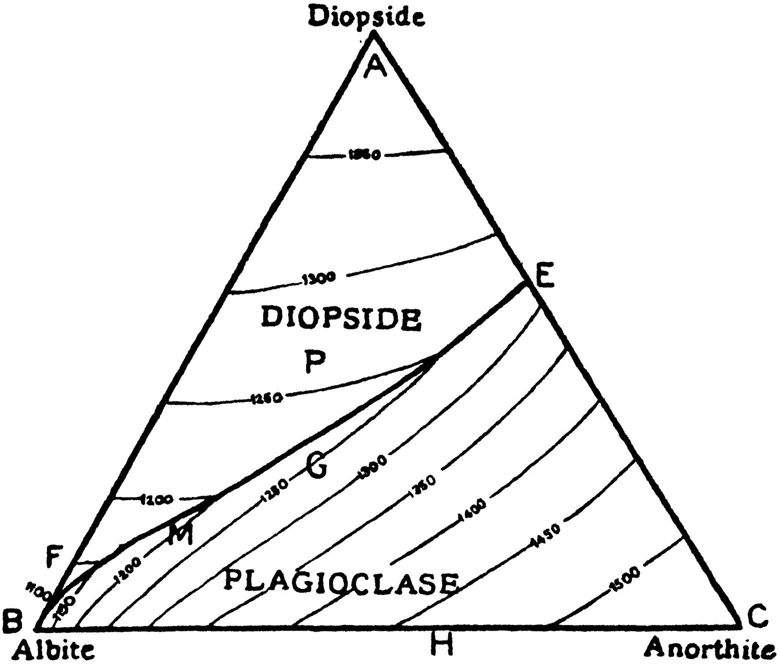

Fig. 8.

The rock resulting from such a process would probably contain phenocrysts of diopside, in a groundmass of diopside and plagioclase.

The analysis of the amphibolite quoted on page 33 shows that the composition of the magma actually corresponds to this upper field (AEF) of the diagram, and we may therefore suppose that some well-crystallised diopside or hornblende was originally the first mineral formed.

It may be supposed that hornblende crystallised instead of diopside under the influence of the volatile components (chiefly water) in the magma, or perhaps it is of metamorphic origin.

For melts possessing a composition corresponding to a point below the eutectic line, the conditions would be reversed—*i.e.*, plagioclase would first separate. This is obviously the counterpart to the crystallisation of the anorthosite, which, as shown above, contains frequent large crystals of plagioclase in a ground-mass of plagioclase and hornblende.

IV. THE ALBTAL GRANITE.

(Hauptgranit.)

The well-known porphyritic granite of Tiefenstein is the most important rock in my observation area. The granite massif to which it belongs, has its eastern boundary in and about Tiefenstein, and from here it extends to Wiesental in the west. It is commonly known as the Albtal Granite (Schill.[1]), but has also various local names. In the Wiesental, for instance, Philipp[2] has named the rock "porphyrartiger Granit," in the Wehratal Erdmannsdörffer[3] called it "Syenit und Amphibol Granit," and in my observation area, in the valley of the Alb, it has been called Albtal Granite (Schill, Vogelsang), or Schluchsee Granite (Kloos[4] Fischer). The people of the locality know it as the "Tiefensteiner Granit."

In the whole of this area the granite resembles its other Hercynian contemporaries (of Central France and S. England), inasmuch as it also possesses big phenocrysts of orthoclase.

The granite of Tiefenstein is a coarse grained, grey, massive, somewhat porphyritic rock, consisting of an aggregate of colourless quartz (4 mm. by 4 mm.), of felspar (usually white and about 4–7 mm. in size) and of shining black biotite (size about 3 mm. by 3 mm.). A portion of the orthoclase is developed as large light brown or light red crystals far exceeding the other components in size. These individuals are sometimes as much as 20 cm. across, twinned according to the Carlsbad law, and variously zoned, biotite being constantly met with and sometimes also albite. (See Figs. 9 and 10.) These large felspars give the rock its porphyritic appearance. On close observation they are usually found (see Fig. 11) to be arranged parallel, with their *c*'axis in one common direction. As regards the zones of biotite, Hirschi thinks that "Sie sind von den wachsenden Orthoklasen fortgeschoben worden."[5] A similar

[1] Geologische Beschreibung der Umgebung von Waldshut. Beitrag z. Statistic der Innenverwaltung des Grh. Baden Heft, 23, Karlsruhe, 1866.

[2] Philipp, Studien im Gebiete der Granite u. umgewandelten Gabbros des mittleren Wiesentals, Heidelberg, 1910. Lit. 48.

[3] Erdmannsdörffer, Diss, Heidelberg, 1901. Lit. 15.

[4] Kloos, Studien in Granitgebiet des südl. Schwarzwaldes, N.J.B. Min. Beilage Band III, 1884.

[5] Hirschi, Hans. Dissertation, Zurich, 1901. Lit. 26.

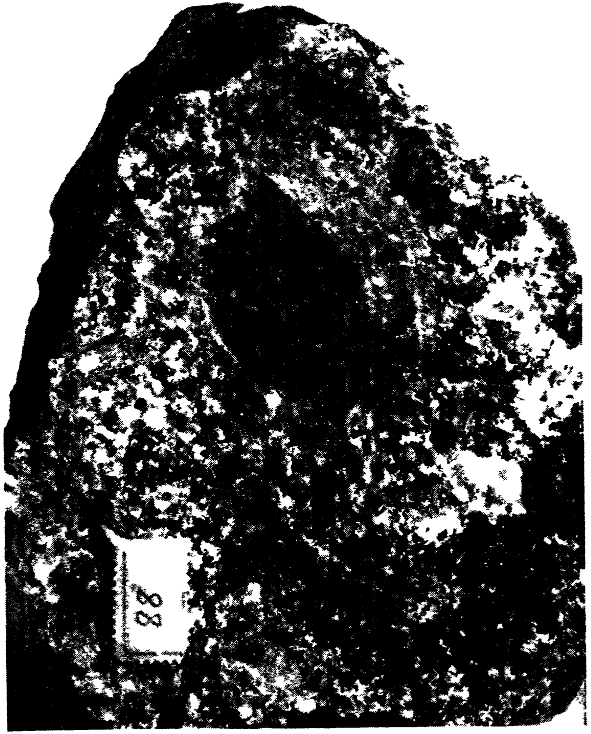

Fig 9

Orthoclase phenocryst in the Albtal Granite zoned with biotite and albite and twinned according to Carlsbad law A biotite concretion is visible in the lower right hand corner $\frac{2}{3}$ Natural size

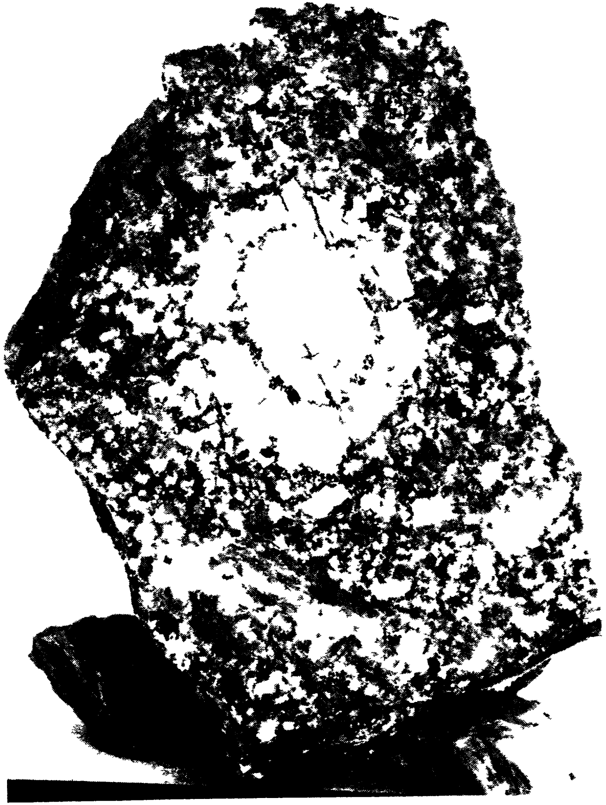

Fig 10

Orthoclase phenocryst in the Albtal Granite zoned with biotite and twinned according to Carlsbad law. $\frac{3}{4}$ Natural size

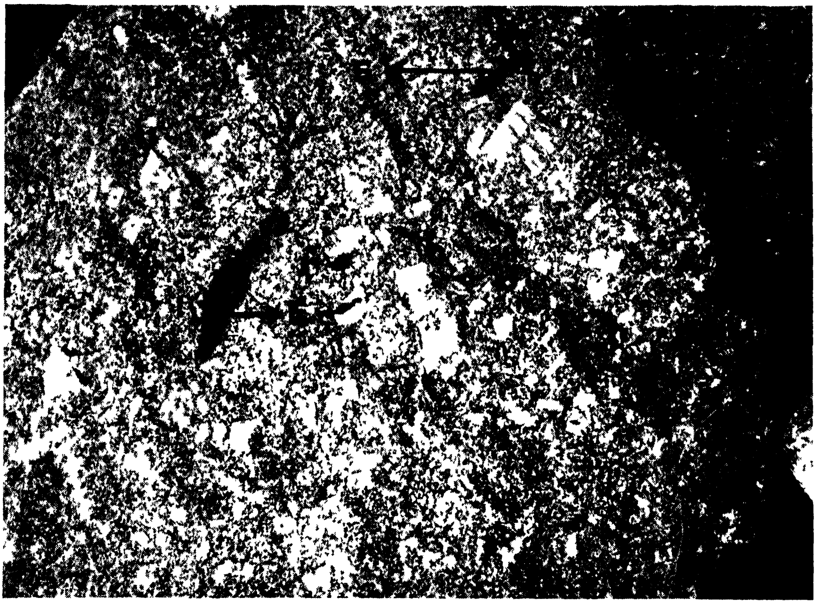

Fig. 11.

Parallel arrangement of the Enclaves (E) and Orthoclase Phenocrysts.

phenomenon is observed in the case of gypsum crystallised within clay deposits, where individuals showing zones of sand or clay are often met with, and it is commonly believed that such aggregation of particles of sand or clay has been called forth by the mode of growth of the crystals. The particles of sand, etc., were pushed away by the growing gypsum individuals. According to Pirsson, such zoning or crowning has been termed " Expansion Structure."[1]

The zones do not extend to the extreme periphery of the phenocrysts, which may be explained by a change in the force of crystallisation during the growth.

It is interesting to note that the biotites and the enclaves of the type " Homœogènes Plésiomorphes " are also found in an arrangement parallel to the felspar phenocrists (see Fig. 11). These facts lead to the conclusion that the porphyritic elements and the enclaves were already developed before the final intrusion of the granite, and were afterwards carried along with the residual liquor, which ultimately crystallised and formed the ground mass. A similar phenomenon is reported in connection with the granite massifs of Cornwall, the contemporaries of the Albtal granite.

Under the microscope the rock shows a hypidiomorphic granitic aggregate of quartz, perthitic K-felspar, plagioclase and biotite. The average volume percentages are about 27 per cent. quartz, 33.5 per cent. K-felspar, 24 per cent. plagioclase and 15.5 per cent. biotite. Muscovite, apatite, chlorite, zircon, orthite, tourmaline, topaz, fluorite, etc., are the accessory minerals of the rock.

Quartz.—It occurs in irregular grains as well as with partly crystalline outline. Its margins are sharp where bounding a plagioclase, jagged, however, against the orthoclase. It is full of gas and liquid bubbles which are sometimes found to be arranged in a pattern of approximately parallel lines.

The *biotites* are brown and pleochroic. The pleochroic colours vary between

$n\gamma = n\beta$	$> n\alpha$
dark brown.	very light brown.

Usually the biotite individuals are found to be partly chloritised with the separation of green slightly pleochroic pennine, opaque grains of magnetite and sometimes of patches of leucoxene and minute needles of rutile. Zircon and orthite appear also as inclusions.

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[1] L. V. Pirsson. On the Phenocrysts of intrusive igneous rocks. American Journal of Science, 1899, 157, pp. 271-280.

Sometimes the biotite individuals appear fringed in the margin through resorption. A chemical analysis of the biotite by Hirschi (1901) gives the following result:—

Comp.	Weight per cent.	Molecular proportions.
SiO_2	35.68	591
TiO_2	4.59	57
P_2O_5	—	—
Al_2O_3	14.48	142
Fe_2O_3	10.46	65
FeO	10.45	145
MgO	11.82	293
MnO	Trace	—
CaO	0.45	8
Na_2O	0.90	14
K_2O	8.48	90
$+H_2O$	1.85	—
$-H_2O$	0.55	—
Total	99.71	

Sp. gr.=3.034

Molecular values according to Niggli.	
si	72
al	17.5
fm	69.0
c	1.0
alk	12.5
k	0.86
mg	0.52
c/fm	0.01
ti	6.5

Magmatic field :
Section I.

Felspars.—The big phenocrysts possess very good cleavage lines parallel to (010) and (001), while they are easily separable in the direction parallel to (110). Crystals of these phenocrysts, obtained from the granite débris, show the faces (001), (110), (130) and (201). Many of the individuals are twinned according to the Carlsbad law. Microscopical properties confirm them as orthoclase. Their extinction angle on (001) = 0°.

The refractive index of the felspar is lower than that of quartz and of Canada balsam. The surface is usually partly sericitised. Inclusions of biotite, quartz, albite and apatite are common. As stated above, the orthoclase phenocrysts are zoned (crowned) with rings of milk white felspar (see Fig. 7). Microscopical examination of the latter shows that it consists of innumerable small crystals of albite or albite-oligoclase which may have the composition $Ab_{85}\ An_{15}$. A disturbance in the equilibria of the melt is supposed to be the main reason for such zoning.

A chemical analysis of an orthoclase phenocryst, free from biotite or albite shows the following result :

ORTHOCLASE. ANALYSED BY S. K. RAY.

Comp.	Weight per cent.	Molecular proportions.	Molecular proportions according to Niggli.		
				Actually found	Theoretical
SiO_2	64.79	1,079	si	305	300
Al_2O_3	19.60	192			
Fe_2O_3	0.86	5	al	54	50
CaO	Trace	—	fm.	4	—
BaO	0.51	3	c	1	—
MgO	0.18	—	alk	41	50
Na_2O	0.78	4			
K_2O	12.50	133	k	0.92	1.0
$+H_2O$	42	—	mg	0.28	—
			c/fm	0.25	—
Total	99.64		si′	+ 41	—

The K-felspars in the main mass of the rock are usually perthitic. Typical microcline with cross-hatching, and of fairly big dimensions is occasionally met with. The *plagioclase* is twinned both according to the albite and Carlsbad laws. Sometimes one of two individuals twinned according to the Carlsbad law is found to be further twinned according to the albite law. It is optically positive, and its other properties confirm it to be an albite-oligoclase. Ab_{85} An_{15}.

From the occurrence of such minerals as fluorite, tourmaline, topaz, orthite, etc., it is evident that the magma was rich in gaseous fluxes, and that the rock was invaded by these during and after its solidification.

On page 69 I have described the occurrence of tourmaline suns. An orthite crystal occurring in the rock has been studied in detail. A drawing and the results of crystallographical studies will be found on page 51 of this paper. Beautiful violet crystals of fluorite occurring on a natural cleavage plane of the rock were collected by Prof. Niggli. On examination I found them to be bounded by the faces (100) and (111).

A chemical analysis of the rock undertaken by me is published in this paper, page 48. Hirschi was the first to analyse Albtal granite. Another analysis of the rock has been published by

Suter. The molecular values (according to Niggli) of these analyses are as follow :—

	si.	al.	fm.	c.	alk.	k.	mg.
Hirschi (1901)	270	38	25	12	25	0.41	0.52
Ray (1924) ..	283	39	21	16	24	0.57	0.54
Suter (1924) ..	287	36	20	11	33	0.39	0.55
Average ..	280	38	22	13	27	0.46	0.54

Directions of the natural cleavage planes of the Albtal granite and their relation to the strike-direction of the dykes.

TABLE 1.

Directions of the natural cleavage planes of the Albtal granite. Nos. 1–4, were measured in the Ibach valley, and the rest at Tiefenstein.

1. 310° N.E.
2. 310° N.E.
3. 60° N.W.
4. 35° N.W.
5. 53° N.W.
6. 40° N.W.
7. 80° W.N.W.
8. 320° N.E.
9. 285° E.N.E.
10. 20° N.N.W.
11. 295° E.N.E.
12. 37° N.W.
13. 35° N.W.
14. 300° E.N.E.
15. 4° W.N.W.
16. N.—S.
17. 300° E.N.E.
18. 35° N.W.
19. 290° E.N.E.
20. 40° N.W.
21. 45° N.W.
22. 320° N.E.
23. 315° N.E.
24. 325° N.E.
26. 35° N.W.
27. 300° E.N.E.
28. 303° E.N.E.
29. 35° N.W.
30. 305° E.N.E.
31. 305° E.N.E.
32. 35° N.W.
33. 30° N.W.
34. 347° N.N.E.
35. 300° E.N.E.
36. 355° N.N.E.
37. 45° N.W.

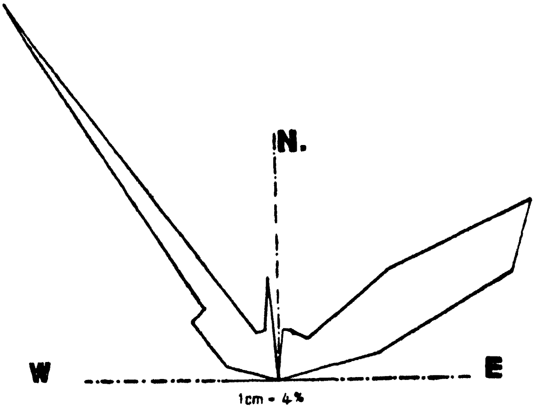
The cleavage directions noted above (Table 1.) can be summarized as follows :—

TABLE 2.

	0°–10°	11°–20°	21°–30°	31°–40°	41°–50°	51°–60°	61°–70°	71°–80°	81°–90°
Number	2	1	1	9	2	2	0	1	0
Per cent.	5.4	2.7	2.7	24.3	5.4	5.4	—	2.7	—

	270°-280°	281°-290°	291°-300°	301°-310°	311°-320°	321°-330°	331°-340°	341°-350°	351°-0°
Number	0	2	5	6	3	1	0	1	1
Per cent	0	5.4	13.5	16.2	8.1	2.7	0	2.7	2.7

From the above data and taking 1 cm. = 4 per cent. a "Kluftrose"[1] of the natural cleavage planes of the Albtal granite has been constructed (Fig. 12). It is quite clear that in the figure the most common protuberances are characterised by N.E. and N.W. directions. These are also the general strike directions of the dykes occurring in the granite and in the gneisses in the neighbourhood of the granite. Cracks and fissures formed in the granite mass as the result of cooling and contraction served as the outlets for other differentiates of the granite giving rise to the dykes of aplite, granite porphyry and lamprophyre rocks. The general directions of the natural cleavage planes therefore naturally coincide with those of the dykes.



"Kluft-rose" of the Albtal granite.

See page 47. (Fig. 12).

Different types of enclaves that are a very common feature of the Albtal granite will be described in the next chapter.

The schistose granite, sometimes found in the marginal regions of the Albtal massif, is seen under the microscope to possess a breccious structure.

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[1] Cloos. See lit. 7.

The injection gneisses in the contact area of granit and gneiss by the Albtal Strasse, South of the Wirtshaus, Tiefenstein, are characterised by the possession of abundant hornblende together with diopside, biotite, quartz and felspar. Orthite, apatite, chlorite, etc., are the accessories. This amphibole gneiss shows a granoblastic structure.

A chemical analysis of the rock gives the following result :—

Albtal Granite

(from the quarry, N. of Schlossberg, Tiefenstein).

Analysed by S. K. Ray.

Comp.	Weight per cent.	Molecular proportions.
SiO_2	67.01	1116
TiO_2	0.87	11
P_2O_5	0.10	1
Al_2O_3	15.85	155
Fe_2O_3	1.92	12
FeO	0.96	13
MnO	0.06	1
MgO	1.80	45
CaO	3,54	63
BaO	Trace	—
Na_2O	2.48	40
K_2O	5.03	53
$+H_2O$	0.58	—
$-H_2O$	0.01	—
Total..	100.21	

Molecular proportions according to Niggli.	
si	283
al	39
fm	21
c	16
alk	24
k	0.57
mg	0.54
c/fm	0.76
ti	2.79
p	—
si′	+ 87
Section	V

Specific gravity = 2.68.
Magmatype = Normal granitic.

Norm of the granite :—

Mineral	Weight per cent.
Apatite	0.3
Rutile	0.88
Orthoclase	29.46
Albite	20.96
Anorthite	16.68
Corundum	0.2
Magnetite	2.78
Hypersthene	4.76
Quartz	23.46

By measurements on several thin sections the constituents of the Albtal Granite were found to be as follows :—

Mineral.	Volume per cent.	Sp. Gr.	Weight per cent.
Quartz	26.5	2.65	26.2
Orthoclase, Microcline, etc.	33.5	2.57	32.2
Plagioclase	24.5	2.63	24.1
Biotite	15.5	3.03	17.5

As only rock free from orthoclase phenocrysts was powdered for analysis, the porphyritic crystals in the thin section were not included in the measurement.

Let us now see how far the analyses calculated from the above data agree with the actual analysis published on the last page. The composition of the phenocrysts is known from my analysis published on page 45, and that of the orthoclase in the ground mass may be taken as the same. The composition of quartz offers no difficulty, and that of biotite is known from Hirschi's analysis.[1] From its optical properties the composition of the plagioclase has been assumed as $Ab_{85}An_{15}$ or Ab_6An_1. The accessory minerals are neglected.

Constituents.	Quartz.	Orthoclase.	Plagioclase.	Biotite.
SiO_2	100.00	64.79	64.9	35.68
TiO_2	—	—	—	4.59
P_2O_5	—	—	—	n.d
Al_2O_3	—	19 60	22.1	14.48
Fe_2O_3	—	0.86	—	10.46
FeO	—	n.d.	—	10.45
MnO	—	n.d.	—	trace
MgO	—	0.18	—	11.82
CaO	—	trace	3.0	0.45
BaO	—	0.51	—	—
Na_2O	—	0.78	10.00	0.90
K_2O	—	12.50	—	8.48
$+H_2O$	—	0.42	—	1.85
$-H_2O$	—	n.d.	—	0.55
Totals	100.00	99.64	100.00	99.71
Percentage of mineral in rock	26.2	32.2	24.1	17.5

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[1] Loc. cit. p. 44.

Constituents.	Quartz × 26.2 per cent.	Orthoclase × 32.2 per cent.	Plagioclase × 24.1 per cent.	Biotite × 17.5 per cent.
SiO_2 ..	26.2	20.88	15.64	6.22
TiO_2 ..	—	—	—	0.80
P_2O_5 ..	—	—	—	—
Al_2O_3 ..	—	6.31	5.31	2.53
Fe_2O_3 ..	—	0.28	—	1.83
FeO ..	—	—	—	1.83
MnO ..	—	—	—	—
MgO ..	—	0.06	—	2.07
CaO .. BaO ..	—	0.16	0.72	0.08
Na_2O ..	—	0.25	0.41	0.16
K_2O ..	—	4.34	—	1.48
$+H_2O$ ..	—	0.13	—	0.32
$-H_2O$ ..	—	—	—	0.08
Totals ..	26.2	32.31	24.1	17.46

The figures obtained from the preceding table are as follows :—

Constituents.	Analysis by S.K.R.	Calculated Composition.
SiO_2	67.01	68.94
TiO_2	0.87	0.80
P_2O_5	0.10	—
Al_2O_3	15.85	14.15
Fe_2O_3	1.92	2.11
FeO	0.96	1.83
MnO	0.06	—
MgO	1.80	2.13
CaO	3.54	0.96
BaO	trace	
Na_2O	2.48	2.82
K_2O	5.03	5.82
$+H_2O$	0.58	0.45
$-H_2O$	0.10	0.08
Totals	100.30	100.09

It will be seen that the agreement between calculated and actual composition is reasonably good.

Orthite.

Face (100) best developed; (001) smaller than (100); $(\bar{1}01)$ very badly developed. One end of the crystal is broken, at the other end the crystal is bounded by the face $(\bar{1}11)$.

Table.

	Angle observed.		Angle according to Hintze.[1]
001 : 100	64°57′–65°49′	.. ..	64°59′
001 : $\bar{1}01$	62°42′–63°35′	.. ..	63°24′
$\bar{1}11$: $11\bar{1}$	70°56′–71°36′	.. ..	71°38′

Insignificantly developed are the faces $(\bar{2}01)$, $(\bar{2}03)$, and $(\bar{1}02)$.

The angle between 001 : $\bar{2}01$ = 86°23′ — 87°23′. Hintze gives it as 89°1′. Reliable measurements of the refractive indices and other optical properties could not be obtained, as the crystal was quite opaque. A drawing of the crystal is given in Fig. 12 (*a*).

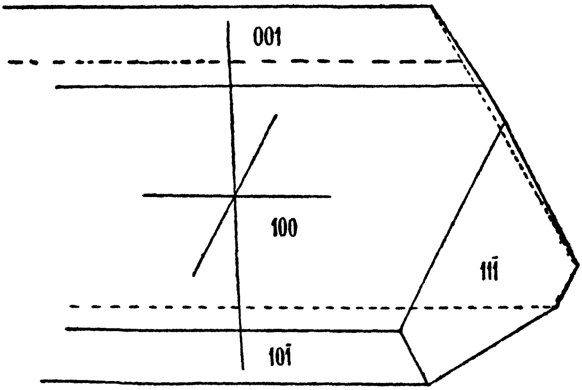

Fig. 12 (*a*).

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[1] Lit. 26 (*a*).

V. THE ENCLAVES.

One of the most important features of the granite of Albtal is the occurrence therein of various kinds of enclaves. One type of enclave, the commonest of all, often as big as a football, contrasts so markedly by its dark colour and fine texture with the granite, that it is easily noticeable even to the most untrained eyes of an Albtal sightseer.

Dr. Julius Schill [1] observed the enclaves and believed them generally to be inclusions of some foreign rock such as fine grained granite or gneiss. In some cases he observed that the felspar phenocrysts of the Albtal granite intruded into the body of the enclaves, and arguing in the same way as Philipp,[2] supposed that these are contemporaneous with the granite. The formation of enclaves of the latter type, was, according to Schill, the result of differentiation in situ of the granite.

Deecke passes over these interesting formations with some summary remarks, mentioning them in connection with the description of the fifth granite massif of the Black Forest (*i.e.*, Albtal massif).[3] It is not known whether Schill or Deecke made any microscopical studies of the enclaves.

An historical account of the work done on the enclaves up to 1905 has been published by Riegner in his thesis.[4] In this paper, as well as in many other works,[5] Prof. Milch and he have published a number of analyses of the enclaves and country rocks of Strigau, Silesia.

Riegner, however, does not make any mention of the classical work on the enclaves published by M. Lacroix in 1904. Holland's extensive work on the "Schlieren" of the Indian rocks was also overlooked by Riegner.

The latest attempt at systematic classification of the enclaves is due to Erdmannsdörffer.[6]

In describing the enclaves in my area, I have followed the classification put forward by Lacroix and have used his terminology.[7]

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[1] Schill. See lit. 60, p. 81.

[2] Philipp. Quart. Journ. Geol. Soc.-Lon., 1882, p. 216.

[3] Deecke. Geologie von Baden. Erster Teil, Berlin, 1916, p. 136.

[4] Riegner: "Chemische Beiträge zur Kenntnis basischer Constitutionsfacies granitischer Gesteine." Diss. Breslau, 1909.

[5] Milch & Riegner. N. J. B., Min., 1910, Beilage Bd. 29. "Ueber basische Conc. im granit von Strigau," and others.

[6] Erdmannsdörffer. See lit. 16.

[7] Lacroix. La Montagne Pelée et ses Eruptions, Paris, 1904.

As Lacroix's classification is solely based on conditions obtaining in volcanic rocks, some minor modifications have had to be introduced to render it applicable to the altered conditions of plutonic rocks.

The classification is founded on chemical as well as structural data. Taking the magma from which the enclave is formed, to be of primary importance we distinguish between :

Enclaves Homœogènes.—This expression is taken to include all those enclaves that were formed from the same magma as that of the enclosing rock, but without any essential action of the gaseous fluxes of the same.

Enclaves Pneumatogènes.—Under this term are included all those enclaves that are formed by the action of the gaseous fluxes contained in the magma.

Enclaves Enallogènes.—These are composed of fragments foreign to the magma.

Enclaves Polygènes.—This term is taken to mean all those enclaves that were formed by the action of the magma or its volatile fluxes on a pre-existing enclave.

The first and most important of these groups is subdivided according to *structure* in the following way :

Enclaves Synmorphes.—Those " Enclaves Homœogènes " that consolidated under the same physical conditions as the enclosing rock and therefore possess texture and structure identical with the enclosing rock are named " Enclaves Synmorphes."

Enclaves Plèsiomorphes.—Under this name Lacroix included all those " Enclaves Homœogènes " that originated as segregation products or as concretionary forms from the same magma from which the enclosing rock was formed. The structure of the enclave is similar, but not identical, with that of the enclosing rock.

Enclaves Allomorphes.—Under this term Lacroix included all those " Enclaves Homœogènes " that were formed from the same magma as the enclosing rock, but were consolidated under different physical and chemical conditions and, therefore, possess a structure different to that of the enclosing rock.

And, finally, again the " Enclaves Homœogènes " are divided *mineralogically* into :

Homologues. — All those enclaves that possess the same *mineral composition* as the enclosing rock, but not necessarily the same chemical composition are designated as "Enclaves Homologues."

Antilogues.—If the mineral composition is different we speak of "Enclaves Antilogues."

The attached Table 3 shews the position occupied by the enclaves of the Tiefenstein area in the above system.

(i) Classification of the Enclaves.

Table 3.

ENCLAVES HOMŒOGÈNES.*

Structural Classification.	Mineralogical Classification.	Examples in the Tiefenstein Area.	Enclosing rock.
Synmorphes ..	Homologues	Not known	Not known.
	Antilogues	(*a*) Biotite Suns	Schlossberg granite.
		(*b*) Enclaves of the Second Order.	Orthoclase biotite apatite enclave.
		(i) Dark (rich in biotite)..	,, ,,
		(ii) Lighter (rich in felspars)	,, ,,
Plésiomorphes	Homologues	Acid enclaves	Hauptgranit (Albtal granite).
	Antilogues	Basic enclaves. (*a*) Orthoclase biotite apatite enclaves.	,, ,,
		(*b*) Plagioclase biotite Magnetite enclaves.	,, ,,
		(*c*) Biotite Concretions	,, ,,
Allomorphes ..	Homologues	Not known	Not known.
	Antilogues	Not known	Not known.

---

* French expressions used here are identical with the original terminology of Lacroix

ENCLAVES PNEUMATOGENES.

Examples in the Tiefenstein Area.	Enclosing rock.
(*a*) Tourmaline Suns	Schlossberg granite.
(*b*) Do. do. ..	Hauptgranit (Albtal granite).
(*c*) Tourmaline Nodules	Schlossberg granite.

ENCLAVES ENALLOGÈNES.

Examples in the Tiefenstein Area.	Enclosing rock.
(*a*) Biotite gneiss	Hauptgranit.
(*b*) Amphibolite	Hauptgranit.

(ii) Description of the Different Types of Enclaves.

1.—ENCLAVES HOMŒOGÈNES.

The above term is synonymous with "cognate enclave" of Harker, Endogene Einschlüsse of Süss, Urausscheidungen of Zirkel, Endogene Einschlüsse of Erdmannsdörffer, Basische Konkretionen of Rosenbusch and Schlieren of Holland.

A.—Enclaves Synmorphes.

Following Erdmannsdörffer's classification (1) we may call them "Endogene Einschlüsse Type 1 (*a*), where the interval between solidification of the enclave and of the enclosing rock = 0.

Homologues.—No examples of these enclaves are known in the Tiefenstein area.

The following are the examples of the *Antilogue Type.*

(*a*) *The biotite suns in the Schlossberg granite.*—One example of enclave antilogue synmorphes are the Biotite suns in the Schlossberg granite. Megascopically these enclaves have the appearance of small patches of dark minerals with the same texture as the *granite* from which they are separated by the white rings surrounding them. The main difference between the enclave and the enclosing rock (fine-grained aplitic granite) is the colour.

Microscopic characters.—Under the microscope the enclave is found to consist of an hypidiomorphic aggregate of decomposed biotite and plagioclase, perthitic orthoclase, shiny blades of muscovite and fresh corny quartz.

The white ring is very poor in biotite and consists of highly kaolinised felspars, whence the lighter colour.

Microscopic Character of the Individual Minerals.

Biotite.—It is usually decomposed into brown grains of limonite, a fibrous greenish aggregate of chlorite and opaque grains of magnetite. Sometimes the chlorites are quite pleochroic, possessing green to bluish-green pleochroic colours.

Muscovite.—Occurs not only together with biotite as its decomposition product, but also as a primary constituent of pneumatolitic origin. It shows well-developed cleavage lines, a shining silky bluish colour and a high interference colour.

Quartz.—Occurs usually in irregular grains dovetailed with each other and contains innumerable gas bubbles and drops of liquid arranged in line along the imperfect rhombohedral cleavage planes. Sometimes, especially when included within a perthitic felspar, it is very clear and well bounded.

Orthoclase.—Usually perthitic and not decomposed.

Microcline.—Usually with cross-hatching; sometimes also in grains without any twinning lines. Extinction angle on section (001) = 13°.

Plagioclase.—Usually with polysynthetic twinning and well crystallised, but untwinned individuals optically + are sometimes met with, as inclusions in perthite. Occasionally it shows a zonal development. The periphery of a zoned plagioclase possesses extinction angle = 15°, while the core has an extinction angle = 18°. The ext. angle $\perp n\gamma$ against the crystal edge (001) = 15°. This characterises the plagioclase as about Ab.90 An.10.

The basic core of a zoned plagioclase is sometimes fully saussuritised, with the development of flakes of chlorite and minute grains of limonite.

There is no difference between the structure of the rock and the structure of the enclave. Both also possess the same plagioclase: albite-oligoclase.

The small patches in the orthoclase biotite apatite enclaves (described below) may be cited as another example of the Enclaves homœgènes synmorphes antilogues. Their colour differs from that of the rock in which they are formed, being sometimes lighter and sometimes darker than the main body of the orthoclase biotite apatite enclaves.

Salomon named such enclaves "doppelte Schlierknödel."[1] As they are small, and are contained within a larger enclave of another type, "enclave of the second order" would seem a satisfactory term by which to designate them. Stress must be laid on the point that no genetical significance may be attached to this expression, which is only intended to distinguish them from other types of enclaves.

According to their colour such enclaves may be divided into two groups, and we shall distinguish between "light" and "dark" enclaves of the second order respectively.

β—"*Dark*" *Enclaves of the 2nd Order.*—These enclaves possess the same structure and texture as, but a much darker colour than, the orthoclase biotite apatite enclaves in which they are found in large numbers. They are never seen in the plagioclase biotite magnetite enclaves and have never been found to exceed more than ½ cubic centimetre in volume.

Megascopically they consist almost wholly of shining black blades of biotite, with very little or no cementing material between them. Crystals of plagioclase of much larger size than the biotite are found embedded in the dark mass. These are therefore reckoned as phenocrysts. Examined through a lens the polysynthetic twinning planes of these plagioclases are clearly seen. These dark enclaves of the second order have quite a sharp boundary against the orthoclase biotite apatite enclaves in which they are embedded.

Under the microscope the enclave is seen to consist of blades of biotite in such abundance as is not found in any rock other than the lamprophyre of the locality. It is the ordinary granitic biotite possessing light brown to deep brown pleochroic colours. Grains of pyrites form a common and interesting accessory mineral of the rock. The biotites, usually fresh, are often seen to be chloritised near their contact with pyrites. The latter mineral is not met with in the orthoclase biotite apatite enclave, nor in any other rock in connection with granite.

The other important constituent mineral of the enclave is the plagioclase. It is seen to occur not only as the phenocrysts mentioned above, but forms the ground mass also. It is optically positive, is twinned both according to the albite and Carlsbad laws, and on the face (001) shows an extinction angle= about $-5\frac{1}{2}°$ against the cleavage lines parallel to (010). These properties characterise the plagioclase as a Labradorite ($An_{48}Ab_{52}$).

---

[1] See lit. 63.

It is, therefore, more basic than the plagioclase within the orthoclase biotite apatite enclave.[1].

When decomposed the alteration is generally found to have taken place along the cleavage lines, but sometimes the whole crystal is decomposed, and altered to Saussurite.

Quartz is nowhere present in the inner enclave. Microcline, perthite, quartz, etc., are present in the outer (*i.e.*, the orthoclase biotite apatite) enclave. The biotites and the basic felspars have generally a concentric arrangement about a common centre, and it would thus appear that the dark enclaves of the second order have formed around the primary centres from which crystallisation started. The fact that the felspar is more calcic than in the outer enclave may be similarly construed.

γ. *"Lighter" Enclaves of the 2nd Order.*—These enclaves occur in a similar fashion as the "dark" enclaves mentioned above, within the orthoclase biotite apatite enclaves. As more felspars than biotites have contributed to their formation, they possess a colour lighter than that of the orthoclase biotite apatite enclaves, and still more so than that of the "dark" enclaves of the second order. They are not so common as the dark enclaves, with which, however, they are believed to be contemporary. The latter are the basic differentiates of the same cycle of differentiation of which the "lighter" enclaves of the second order represent the acid pole.

They have not been found within the plagioclase biotite magnetite enclaves and do not exceed more than half a cubic centimetre in volume.

B.—ENCLAVES PLÉSIOMORPHES.

Examples :—

α. *Homologous* type.—The acid enclaves in the Hauptgranit.

β.—*Antilogous* type.—The basic enclaves in the Hauptgranit.

  a. The orthoclase biotite apatite enclaves.
  b. The plagioclase biotite magnetite enclaves.
  c. The biotite concretions.

These enclaves are the same as those called "basische Ausscheidungen of the type Endogene Einschlüsse oder Urauscheidungen," by Erdmannsdörffer.[2]

---

[1] See p. 62. [2] See lit 16.

a. The acid enclaves in the Hauptgranit.—Rosenbusch called these enclaves "Saure Schlieren." They occur in the Albtal Granite with all the characteristics that have been enumerated by Rosenbusch. Seen from far they are easily distinguished from the main mass of the granite by their lighter colour and less porphyritic structure. They occur in small irregular dykes, sending out apophysses into the granite, looking as if intergrown with the latter.

Though usually smaller, they are sometimes found to attain a length of several feet and a breadth of 1—1½ ft. Unlike the other type (*β*), they never seem to possess a rounded or elliptical form. I think they represent the more acid differentiate of the granite magma produced in the same phase of differentiation as the basic type mentioned under type (*β*.) Being more basic in composition and having, therefore, a higher melting temperature, the type (*β*) became solidified long before this type of acid differentiate. The (*a*) type intruded into the semi-liquid granite mass in the form of small dykes, and as the granite magma was still in movement, these were torn into pieces and irregularly pressed into the granite. The *β* type of enclave being partially solidified (plastic) was moulded into more or less elliptical form by the movement with the granite.

Hand-specimens of these enclaves show more liberal development of the colourless constituents than the granite. Further, quartz, orthoclase and biotite, all the chief constituents of the rock, have a much stouter form and therefore give the enclave a much coarser texture than that of the granite. No phenocrysts of orthoclase as large as those in the granite are found.

Average size of the constituent minerals :

Granite :—Quartz, 4 mm. ; Orthoclase, 7 mm. ; Biotite, 3 mm.

Acid enclave :—Quartz 6 mm. ; Orthoclase, 12 mm. ; Biotite, 5.4 mm.

The *quartz* is clear and colourless.

The *felspars* :—Two kinds of felspars are found to occur in the rock. One is brown and appears as phenocrysts and the other is white and is contained together with the quartz in the ground mass. The brown or flesh-coloured felspars are orthoclase. They possess good cleavage lines parallel to (001) and (010), and also a somewhat irregularly developed system parallel to (110). The white type is in part plagioclase. It is sometimes found to be polysynthetically twinned. Sometimes individuals are found to be twinned according to the Carlsbad law, and may be recognised as orthoclase.

Under the microscope the rock is found to consist of a coarse-grained aggregate of quartz, orthoclase, perthite, plagioclase and biotite. Apatite, chlorite, zircon, etc., are the accessories.

The *quartz* occurs both in irregular grains and with crystalline outline. It contains inclusions of apatite, gas bubbles and cavities filled with fluid, the latter arranged along irregular cracks which sometimes exhibit a crudely rectangular arrangement. This leads one to think of an imperfect rhombohedral cleavage of the quartz. It is seen to possess a slightly undulose extinction, or strain shadows, which confirm the fact that the rock has undergone some pressure. Those quartz grains that are enclosed within orthoclase do not, however, show this phenomenon of undulose extinction. These are probably of secondary origin.

Orthoclase occurs both as phenocrysts and in the ground-mass. The latter is usually perthitic, or has undergone decomposition. The phenocrysts show remarkable cleavage lines, non-twinned character and a straight extinction on the face (001).

Plagioclase is polysynthetically twinned, possesses a refractive index lower than that of quartz and is optically positive. Usually it is decomposed, the maximum extinction angle in the zone [010] = −16° to −15° indicating albite. (= about $Ab_{95}\,An_5$).

Sometimes the plagioclase individuals possess a zonal development. The core of a zoned individual has been found to be biaxial positive. Tested by Becke's lines it was found to possess a higher refractive index than the periphery. Sometimes the zoned individuals are found to be twinned, and in such cases the twinning is seen to have commenced at the very core.

Biotite.—It is strongly pleochroic. Its pleochroic colours vary between deep greenish-brown to deep brown.

$$n\gamma = n\beta > n\alpha$$

Deep greenish-brown. Deep brown.

It is crowded with grains of apatite, needles of rutile and zircon with pleochroic haloes. It is usually fresh, but is sometimes chloritised all along the margin. It is ordinary granitic biotite.

β.—The Basic Enclaves in the Hauptgranit.

These constitute the most important enclaves of the granite. They are widely distributed all over the granite, appear as masses of usually elliptical form and are grey to greyish-black in colour. They have a sharp boundary against the granite, from which they are easily distinguished by their remarkably contrasting colour and texture.

Their volume varies between several cubic inches to about a cubic foot or more. They show a certain parallel arrangement (see fig. 11) and uniform distribution within the granite mass. These facts indicate that they have moved with the granite magma.

The enclaves of the Hauptsteinbruch, Tiefenstein, are much darker than those at Humbert's quarry. The results of chemical analysis (see pp. 64 & 66) show that the enclaves found at these two localities have different composition, the darker one being the more basic of the two. Mineralogically also they are not identical, and they possess different specific gravities. These facts tend to indicate that the two types of enclaves resulted from two distinct phases of differentiation.

In very rare cases the enclaves are seen to be bounded by a distinct line of separation between the granite and the enclave. Such rings were also observed by Salomon about some of the enclaves in the Adamello Gruppe.[1] He considered them to be resorption rings.

The chemical and mineralogical composition of the two types of enclaves mentioned above show that we may distinguish between :

> Orthoclase-biotite-apatite enclaves, usually of grey colour, and
>
> Plagioclase-biotite-magnetite enclaves, usually black in colour.

The composition of the two types of enclave (apatite on the one hand and magnetite on the other) suggests that the differentiation process may essentially resemble those reported by Geier from Kiruna and Gellivaare in Sweden.[2] The presence of tourmaline, orthite and other pneumatolytic minerals (see below) confirms the presence of pneumatolytic hydrothermal processes.

a. Orthoclase-biotite-apatite enclaves.—Megascopically the orthoclase-biotite-apatite enclave is found to consist of a fine-grained, lamprophyric aggregate of biotite quartz and felspar and innumerable patches of enclaves of the second order (see p. 57). Many phenocrysts of felspar and quartz are present. These may be identical with the crystals of orthoclase reported by Erdmannsdörffer[3] as occurring within a " Schollen " of granite-porphyry in granite (Thüringen). Arguing in the same way as Erdmannsdörffer as we can say that these quartz and felspar phenocrysts were individuals isolated from granite and afterwards surrounded by the magma of the enclave, thus becoming embedded in the dark rock.

[1] See lit. 63., [2] Niggli. See lit. 38. [3] Erdmannsdörffer, lit. 16.

Microscopically the rock is found to consist of a panidiomorphic aggregate of biotite, quartz, orthoclase and plagioclase. Phenocrysts of plagioclase and quartz are common.

Occasionally the biotite blades are so arranged around a phenocryst of plagioclase as to give rise to a fluidal texture.

The white bounding rim, when present, is found to have a coarser structure than the enclave, but finer than the neighbouring granite. It is almost absolutely free from biotite.

Plagioclase.—1. The phenocrysts usually occur in well-formed crystals, twinned according to the Carlsbad law, possessing biaxial positive character and refractive index lower than that of quartz. The extinction angle against (001) on a section about vertical to $n_\alpha = 74°$; the extinction angle on (001) $= +4°$; in the zone of [010] the maximum extinction angle $= -9\frac{1}{2}°$ and on the section about vertical to $n\gamma$ it is about 20°. All these values indicate albite (about Ab_{90} An_{10}).

2. The plagioclase commonly found in the ground-mass has the following characteristics :—

Elongated prismatic cross-section.

It is better crystallised than quartz and orthoclase, usually offering a straight margin against the former, but signs of resorption are not uncommon in the margin. The interfacial angle between the faces (001) and (100) was measured and found to be = 70°. It is optically biaxial, negative. Its extinction angle on the section about vertical to $n\gamma = 3\frac{1}{2}°$, it possesses broader twinning lamellæ than the other variety of plagioclase. The plagioclase is therefore an oligoclase (about An_{30} Ab_{70}).

The *orthoclase* is usually perthitic. Together with quartz it forms a matrix binding together the crystals of biotite and plagioclase to form the ground-mass as a whole. Sometimes big perthitic crystals occur, which deserve the term phenocrysts. I think these big individuals have, like quartz, "gone astray" from the granite. Sometimes the orthoclase shows hour-glass structure.

Quartz.—It is very badly crystallised. Almost always it is found intergrown with orthoclase. Biotites embedded in quartz usually show a reaction rim of chlorite. It is full of gas bubbles and cavities filled with fluid. It sometimes shows undulose extinction. In some of the sections eutectic intergrowth of quartz and felspar has been observed.

Apatite.—This mineral is so common that it can be classed as a chief constituent of the rock. At least 5% of the whole volume of the section is found to consist of individuals of apatite. It occurs profusely in needles, prisms and grains, as inclusions in all other minerals. It is optically uniaxial, negative, possesses high refractive index, but low interference colours. Cleavage lines parallel to (0001) are usually well developed.

Orthite.—It is the most interesting accessory mineral of the rock. It occurs in small brownish-yellow grains, sometimes as much as $\frac{3}{4}$ mm. across, embedded in biotite or other minerals. Sometimes when the orthite occurs as an inclusion in biotite a part of it is found to be resorbed by the latter.

It possesses well developed crystalline outline, and sometimes shows a zonal development. When zoned, the inner core of the orthite shows optically positive character, higher interference colours and refractive index (measured by Beck's lines) than the outer epidote ring, which is optically negative. The non-zonal individuals are wholly positive.

Usually the mineral is fresh and is surrounded by a pleochroic halo. In addition to the well-marked prismatic cleavage lines, the grains of the mineral are found to be traversed by innumerable irregular cracks. Some of the individuals are twinned and the twinning was observed (in agreement with Weber[1]) to have a direction vertical to the plane of the optic axes, *i.e.*, perpendicular to the plane (010). Its $n_\gamma - n_\alpha =$ about 0.015.

Some of the grains of orthite have no pleochroic halo around them. Weber (*loc. cit.*) has calculated that when the epidote ring about a zonal orthite is broader than 0.005 mm. no pleochroic halo occurs. The cause of the occasional absence of the pleochroic halo in the present case is probably the same.

The pleochroic halo is very narrow, but sharp around a fresh orthite, while it is broader and less dark around a decomposed specimen of the mineral.

It is usually supposed that the epidote mantle around an orthite is of secondary origin, but from the freshness of the epidote and from the gradual transition of the epidote to orthite, as is seen here, it cannot be believed that the mineral is an alteration product. I believe that the epidote has crystallised along with orthite in a mix-crystal system of disturbed equilibrium. Similar instances of primary epidote are reported from various other sources.[2],[3].

Another accessory mineral in the orthoclase-biotite-apatite enclaves is *tourmaline*. It is found in grains within microscopically small druses surrounded by sericite, etc. These druses are believed to have been formed from the pneumatolytic rest solutions entrapped within the enclaves.

[1] Weber. Diss. über Piz Giuf. See lit. 66.

[2] Lacroix. Bull. Soc. Franc. de Min. XII., pp. 139.

[3] Keys. Bull. Geol. Soc. Am., 1893, p. 305.

Other accessories are zircon, leucoxene, chlorite, etc.

Apatite was the first component of the rock to crystallise, the other minerals show the following sequence :—

Biotite—plagioclase—quartz—orthoclase.

It has been stated, however, that some of the enclaves are bounded by a *white ring*. The microscopic examination shows the same to be very poor in biotite and plagioclase, and to consist almost entirely of quartz and orthoclase.

The rapid segregation of melanocratic components that must have taken place for this type of enclave to develop, has left an outer portion correspondingly poor in such components, which now appears as the white ring separating the enclave from usual granite.[1]

A chemical analysis of the rock gives the following result :—

Orthoclase—Biotite—Apatite Enclave.

Analysed by S. K. RAY.

	Weight per cent.	Molecular proportions.
SiO_2	66.25	1,104
TiO_2	1.04	13
P_2O_5	0.82	6
Al_2O_3	11.38	112
Fe_2O_3	2.93	18
FeO	3.05	42
MnO	0.02	—
MgO	4.33	108
CaO	1.46	26
Na_2O	2.23	35
K_2O	6.33	67
$+H_2O$	0.59	—
$-H_2O$	—	—
Total	100.43	

Molecular proportions according to Niggli.	
si	259
al	26
fm	44
c	6
alk	24
k	0.66
mg	0.58
ti	3.00
p	1.4
$\frac{c}{fm}$	0.14
si	+ 63
Section I.	

Specific gravity 2.68

Magma type .. .. Lamprosyenitic.

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[1] See Sir T. H. Holland. Lits. 27 (*a*), 27 (*b*) and 27 (*c*), and also lits. 18, 37 and 54.

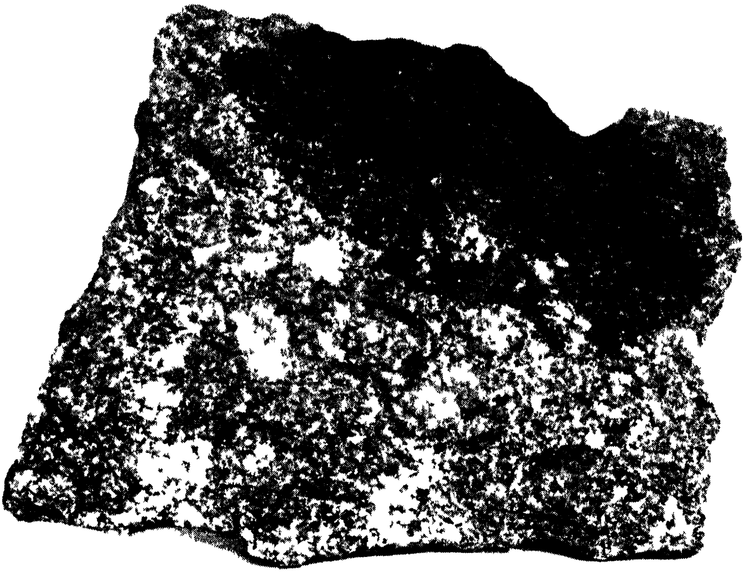

Fig 13

Enclaves Homœogenes Plesiomorphes

Biotite concretion in the Albtal granite (See page 66)

The point marked is a Granite inclusion ⅓ Natural Size

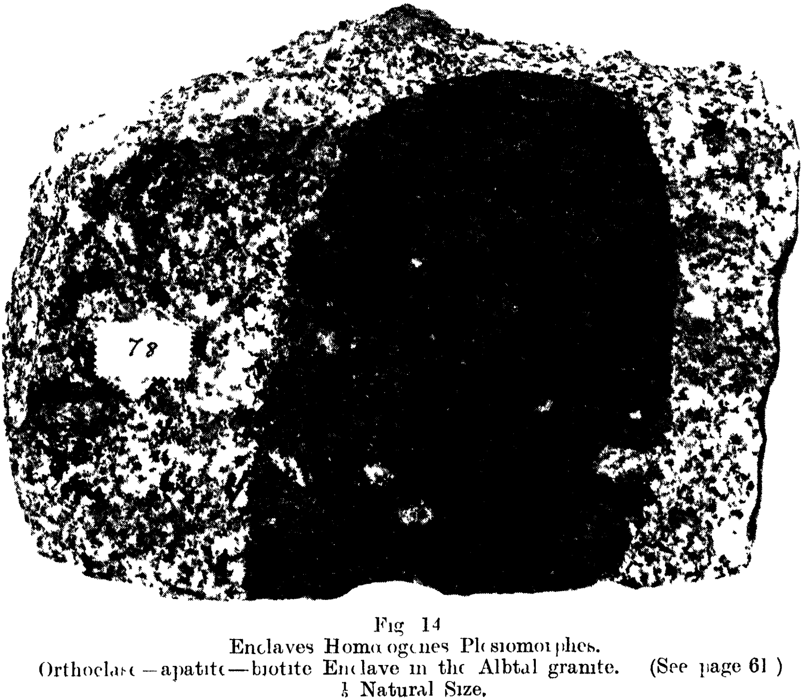

Fig 14

Enclaves Homœogenes Plesiomorphes.

Orthoclase—apatite—biotite Enclave in the Albtal granite. (See page 61)

½ Natural Size.

[*Facing page* 64

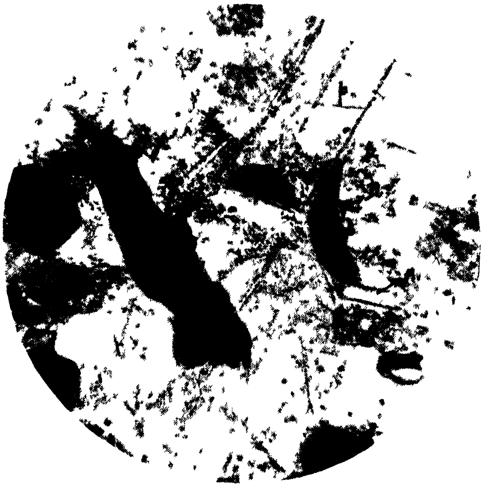

Fig 15

Biotite bounded at one end by a needle of apatite pressed by a growing plagioclase

A Apatite

B Biotite

P—Plagioclase

Magnification × 30

Plane polarized light

Norm of the rock:

Mineral	Weight per cent.
Apatite	2
Rutile	1.4
Orthoclase	37.2
Albite	18.34
Anorthite	1.7
Magnetite	4.1
Corundum	0.46
Hypersthene	13.97
Quartz	20.88

(*b*) *Plagioclase-biotite-magnetite Enclaves.*—The mode of occurrence of these enclaves within the granite is identical with that of the orthoclase-biotite-apatite enclaves. From the latter they may be easily distinguished by much darker colour. Moreover they are almost altogether free from phenocrysts of quartz, orthoclase and plagioclase. Enclaves of the second order are also absent.

Some of these plagioclase biotite-magnetite enclaves possess a rather pressed structure, but usually they are quite massive and compact.

The mineral components of these enclaves as megascopically distinguishable, are felspar, quartz and biotite. All the minerals are quite fresh.

Under the microscope these enclaves are found to be characterised by a hypidiomorphic structure, and by the presence of a relatively large quantity of magnetite, which is altogether absent in the orthoclase-biotite-apatite enclaves. Plagioclase felspars are here much more numerous than in the other type.

The plagioclase-biotite-magnetite enclave consists of about 51 per cent. plagioclase, 10 per cent. orthoclase, 21 per cent. quartz, 16 per cent. biotite and about 2 per cent. magnetite, while the plagioclase constituent of the orthoclase-biotite-apatite enclave does not exceed more than 5 per cent. of the whole rock.

The *plagioclase* of the rock occurs in small elongated rectangles and possesses the properties of an oligoclase-andesine having the composition of about Ab_{70} An_{30}. Sometimes the plagioclase crystals have, during their growth, bent previously crystallised biotite individuals.

The attached Fig. 15 will show how a biotite individual, bounded on one side by a needle of apatite, has been thus pressed by plagioclase.

Zircon, chlorite, leucoxene, apatite, orthite, sericite, paragonite, epidote, etc., are the accessories of the rock.

The sequence of mineral crystallisation is as follows :—

Magnetite——biotite——plagioclase——quartz-orthoclase.

A chemical analysis of the rock shows the following result :—

Plagioclase—Biotite—Magnetite Enclave.

Analysed by S. K. RAY.

	Weight per cent.	Molecular proportions.
SiO_2	62.70	1,044
TiO_2	1.64	19
P_2O_5	0.55	3
Al_2O_3	16.19	159
Fe_2O_3	1.20	7.5
FeO	3.40	47
MnO	0.06	1
MgO	1.80	45
CaO	4.58	82
Na_2O	3.16	52
K_2O	3.18	34
$+H_2O$	1.45	—
$-H_2O$	0.05	—
Total	99.96	

Molecular proportions according to Niggli.	
si	240
al	36
fm	25
c	19
alk	20
k	0.4
mg	0.42
ti	4.00
p	—
$\frac{c}{fm}$	0.76
si′	+60
Section V.	

Specific gravity	2.74
Magma type	Granodioritic.

Norm of the rock :

Mineral	Weight per cent.
Apatite	1
Rutile	1.72
Orthoclase	18.9
Albite	26.8
Anorthite	20.00
Magnetite	1.8
Corundum	0.02
Hypersthene	9.39
Quartz	18.2

(*c*) *The biotite concretions.*—These concretions are usually found to occur as irregular veins or lenticular bodies ; they rarely attain a size of about 10 in. by 8 in. (fig. 13) ; and are distributed all through the granite mass.

Megascopically they are found to consist of innumerable shining black blades of biotite, much smaller than those usually found in the granite, cemented together by a ground-mass of quartz easily recognisable by its glassy lustre and conchoidal fracture. The boundary between the enclave and the granite is not a very well marked one. The granite and the enclave are found to penetrate into one another and sometimes the enclaves are penetrated by granite. (See fig. 13.)

A vein-shaped enclave of this type examined under the microscope shows the following characters :—

The *biotites* occur mostly in very minute brown pleochroic blades, full of needles of *apatite,* grains of *orthite* and *zircon* surrounded by pleochroic haloes and spots of leucoxene. Rutile needles are not seen. Most probably they have all been decomposed and replaced by the spots of *leucoxene.* Usually the biotites are quite fresh, but in many cases, however, they are seen to be chloritised.

All the colourless constituents of the rock are wholly decomposed. No quartz was found in the particular specimen examined. Innumerable scales of *sericite* are seen. Probably they constitute alteration products of orthoclase.

An interesting accessory is *tourmaline.* It occurs in minute green pleochroic grains, which are difficult to distinguish from the chlorite on account of their minute size. But their identity can be established by the high refractive index, the fairly strong pleochroism and high interference colour.

Some *Magnetite* occurs.

The orthoclase in the granite next to the enclave is also almost wholly decomposed. It seems as if hydrothermal rest solution retained within the biotite aggregate had given rise to auto-pneumatolysis or auto-metamorphism of the rock.

Enclaves Homœogènes are not only common in the Albtal massif but form a constant feature of almost every massif of eruptive rock.

I believe that they are formed as the result of a differentiation similar to that which leads to the separation of lamprophyre rocks in a big natural magma basin. In the case of the Enclaves Homœogènes the range of differentiation is restricted and perhaps only partly complete. The resulting products must therefore occur on a much smaller scale than is the case with the full lamprophyric differentiation.

The Enclaves Plésiomorphes reported as occurring in the granite massif of Strigau,[1] in the granite massif of Lausitz[2] and in the syenites of North Sweden,[3] are believed by the respective authors to be the result of differentiation *in situ.*

Movements that took place in the magma basin after the formation of the felspar phenocrysts and the enclaves, produced the stretching of the originally rounded forms of the latter into the present oval shapes, and the parallelism now found existing between the enclaves and the phenocrysts. (See fig. 11.)

2.—ENCLAVES PNEUMATOGÈNES.

A.—Tourmaline suns in the Schlossberg granite.

These formations appear as patches consisting of needles of tourmaline roughly radiating from a central point. The patches are surrounded by reaction rims which consist of decomposed (kaolinised) orthoclase, muscovite and quartz, and the whole possesses the appearance of greisen. The rims are of much lighter colour than the granite.

Under the microscope all the constituent minerals within the enclave zone with the exception of the tourmalines and quartz, are, usually found to be wholly or anyway partly decomposed. Sericite forms a mosaic within the orthoclase. The orthoclase has sometimes separated hæmatite. The plagioclase which is an albite-oligoclase is also seldom found fresh. The tourmalines are usually of the brown Fe– and Mg– variety. Sometimes they are green or blue. They, too, have occasionally been decomposed with the formation of sericite and limonite.

Zoisite and apatite are the accessories of the rock.

B.—The tourmaline nodules in the Schlossberg granite are of elliptical form, sometimes about 5 by 1½ cm. in size. They have a hollow cylindrical core and a reaction rim consisting of greisen minerals. The tourmalines found here are usually fresh, but the other minerals within the enclave zone are all fully or partly decomposed. The other mineral constituents of these enclaves correspond with those of the tourmaline suns mentioned above.

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[1] Milch & Riegner: Ueber basische Konkretionen in dem Granit von Striegau. N.J.B. Min. 1910. Bd.29.

[2] Sommer: Beitr. z. Petrochem. Kenntnis des Lausitzer Granitmassivs. Diss. Leipzig 1915. pp. 12 & 13.

[3] Geiger: Bas. Schliergebilde in einigen N. Schwedischen Syeniten. Geol. For Fõrhandl Bd. 34 H.2. p. 209. Feb. 1912.

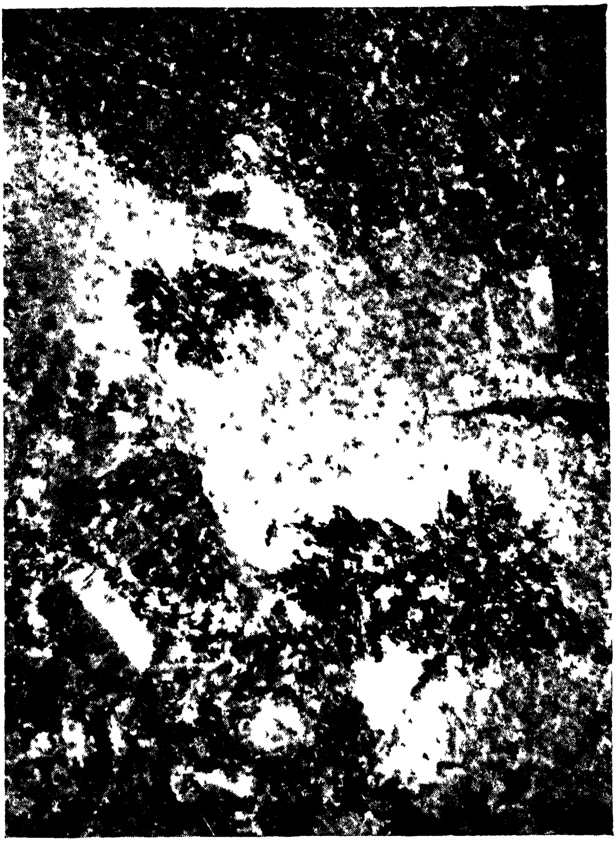


Fig 16.

ENCLAVES PNEUMATOGENES.

Tourmaline suns accompanying an aplite dyke in the Albtal granite ½ Natural size

C.—Tourmaline suns in the Hauptgranit.—That the Hauptgranit was attacked after its consolidation by various pneumatolytic agents is evident from the presence of the tourmaline suns and fluorite. In the attached figure we find that radiating patches of tourmaline occur within an aplite dyke in granite, thus definitely establishing the fact that pneumatolytic agents occurred at the time of the formation of the aplite. (See fig. 16.) The occurrence of these suns is not restricted to the dyke alone, but can be traced in the main body of the granite itself. The minerals near the tourmaline suns are as a rule decomposed, thus resembling those of the tourmaline suns in the Schlossberg granite. With the exception of topaz the mineral constituents are exactly the same as those mentioned in connection with the Albtal granite.

The *topaz* occurs in colourless crystals of 6 or 8-sided cross-section. It possesses prismatic cleavage lines, high relief, straight extinction and low interference colours. Optically it is biaxial and positive.

3.—ENCLAVES ENALLOGÈNES.

Enclave of biotite-gneiss in granite.—Occasionally we come across inclusions of biotite gneiss in the Albtal granite. They must be regarded as blocks from the gneiss roof which sank down into the still molten granite magma. The enclaves possess the characteristic texture of a schistose rock and consist of alternate layers of biotite and of quartz-felspar. The enclaves have undergone alteration by contact and the biotite was afterwards partly decomposed and changed into chlorite.

The boundaries of the gneiss enclaves are quite irregular. It appears that the gneiss has been partially resorbed by the granite and obscure reaction rims are sometimes met with around the enclaves.

Under the microscope the enclaves are found to consist of a granoblastic to poiciloblastic aggregate of quartz, orthoclase, plagioclase (albite-oligoclase), and biotite. Rutile, zircon, apatite, etc., are the accessories.

The *amphibolite* enclaves possess characteristics identical with those of the amphibolite rocks mentioned on page 30. Signs of slight resorption are observed in the margin.

TABLE 4.—*Mean Molecular Values of the Granites, Enclaves and Lamprophyres of the Southern Black Forest.*

	si	al	fm	c	alk	
1	280	38	22	13	27	Mean molecular values of the granite.
2	249.5	31	34.5	12.5	22	,, ,, ,, ,, enclaves.
3	162.5	25	44	17	14	,, ,, ,, ,, lamprophyres.

TABLE 5.—*Albtal Granite, its Enclaves and accompanying Lamprophyres.*

	si	al	fm	c	alk	k	mg	c/fm	
1	283	39	21	16	24	0.57	0.54	0.76	Albtal granite, Tiefenstein.
2	280	38	22	13	27	0.46	0.54	0.54	Mean of Albtal granite compiled from the analyses of Hirschi, Ray and Suter.
3	270	38	25	12	25	0.40	0.52	0.81	Albtal granite.
4	259	26	44	6	24	0.66	0.58	0.14	Orthoclase - biotite-apatite enclave.
5	240	36	25	19	20	0.40	0.42	0.76	Plagioclase - biotite-magnetite enclave.
6	233	38	25	18	19	0.38	0.26	0.74	Lamprophyre, Laufenburg.
7	197	29	33	18	20	0.52	0.54	0.54	Lamprophyre, Wehratal.
8	180	24	39.5	16.5	20	0.61	0.59	0.42	Do. do.
9	167	25	47	16.0	12.0	0.54	0.62	0.35	Lamprophyre, Laufenburg.
10	162.5	25	44	17.0	14.0	0.54	0.59	0.43	Mean of the lamprophyres of Laufenburg, Wehratal, and Albtal.
11	143	20	46	14	20	0.53	0.76	0.31	Lamprophyre, Laufenburg.
12	140	21	52.5	17	9.5	0.60	0.62	0.32	Lamprophyre, Tiefenstein.

(iii) Differentiation of the Enclaves.

Two analyses of " Enclaves Homœogènes " of the Tiefenstein area will be found on pages 64 and 66 in this paper. It is interesting to note that one of the enclaves is characterised by high value of *fm* and the other by high value of *c*. The values respectively attained are common with lamprophyres, which in the same area often show both *fm* and *c* enrichment. Graphs, according to Niggli, containing the molecular values of the granite, enclaves and the corresponding lamprophyres, show a series of continuous curves. (See Figs. 17, 18, 19.)

The mean molecular values of the Albtal granite, lamprophyres and enclaves of the Southern Black Forest are shown in Table 4. The graph of these values (according to Niggli) is shown in Fig. 17.

We see that the molecular values of the enclaves here occupy an intermediate position between those of the granite and the lamprophyre. Of course the enclave lies near the granite, but from the evenness of the curves and from the molecular values of some of its components, *e.g. fm*, which rises suddenly in the enclave, a tendency to lamprophyric differentiation is quite clear.

In particular the positions of the points representing the molecular values of one of the enclaves (*si* 240, Fig. 19) correspond with the positions found by interpolating between the values of the granite *si* 283 and some of the lamprophyres. (Table 5, Fig. 19.)

The nature of this differentiation as represented by the curves may be resumed as follows :

Decreasing *si* is accompanied by a regular decrease of *al* and *alk* and a continuous rise of *fm*. *c* is higher in the lamprophyres and enclave than in some of the granites, but otherwise remains remarkably constant.

These features are characteristics of the so-called *fm*- to *fm-c*-differentiation tendency of the lamprophyres. (See Niggli and Beger, Gesteins- und Mineralprovinzen, vol. 1, p. 476.)

The enclave in the other diagram, Fig. 18, is characterised by a high *fm* value. At least one lamprophyre is known in the neighbourhood (see Table 5, No. 11) which, with the exception of its *si* value, corresponds remarkably with the molecular values of the enclave. (See Fig. 18 and Table 5.)

Not only here in the Black Forest, but in other areas also, the enclaves homœogènes show a differentiation similar to that underlying the differentiation of the lamprophyre rocks. As an example, the Striegau area in Silesia may be quoted.

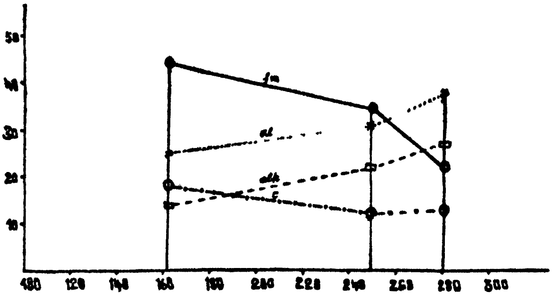


Fig. 17.

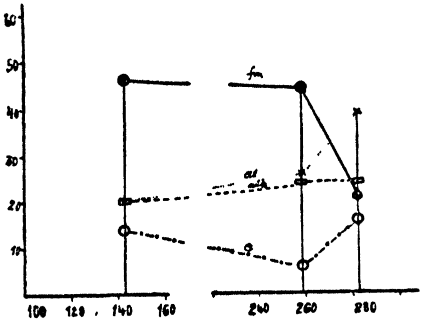


Fig 18

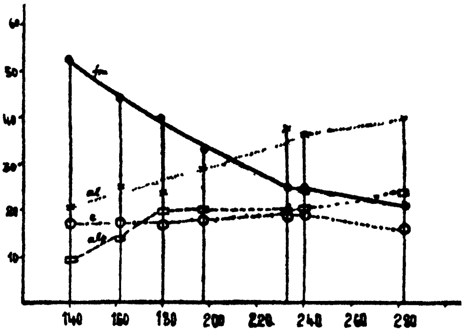


Fig 19

Differentiation diagrams according to Niggli of the granite, enclaves and lamprophyres of the S. Black Forest.

TABLE 6.—*Country Rocks and Enclaves, Striegau, Silesia.* (*Riegner, Diss, Breslau,* 1909). (*Milch & Riegner. See lit* 37.)

	si	al	fm	c	alk	k	mg	ti	p	c/fm	Section.	Rock, Locality, etc.
1	469	46.0	7.0	5.0	42.0	0.47	0.42	—	—	0.71	V	Aplite dyke in granite, passing through an enclave.
2	414	44.0	9.0	5.5	41.5	0.40	0.26	—	1.0	0.61	IV	Central part (core) of an enclave.
3	411	41.5	12.5	6.5	39.5	0.52	0.30	1.0	0.33	0.52	IV	Biotite granite, next to an enclave.
4	375	40.0	16.5	9.5	34.0	0.44	0.25	0.62	0.34	0.58	IV	Typical granite of Striegau.
5	355	39.5	18.5	17.0	25.0	0.50	0.58	—	—	0.92	V	Granite, Pfafenburg, Striegau, Silesia.
6	352	37.0	22.0	10.0	31.0	0.49	0.45	0.60	1.2	0.45	IV	Coarse grained aplitic enclave in granite.
7	324	35.0	25.5	8.0	31.5	0.44	0.25	0.56	0.84	0.31	III	Border of an enclave.
8	286	33.0	33.5	8.0	25.5	0.45	0.21	0.75	0.50	0.24	II	Hornblende biotite granite.
9	277	35.0	30.0	6.0	29.0	0.45	0.19	1.6	0.80	0.20	II	Fine grained dark enclave.
10	256	30.0	36.0	11.0	23.0	0.22	0.11	0.70	0.70	0.31	III	Biotite plagioclase enclave.
11	220	31.0	37.0	8.0	24.0	0.34	0.15	1.50	0.70	0.22	II	Enclave with lamprophyric structure.
12	208	33.0	31.0	13.0	23.0	0.32	0.39	1.80	0.82	0.42	III/II	Border of an enclave.
13	169	29.0	39.0	12.0	20.0	0.28	0.38	1.80	0.72	0.31	III	Dark enclave in granite (Hornblende + plagioclase + biotite).
14	168	34.5	28.0	23.0	14.5	0.26	0.60	—	—	0.82	V	Enclave in granite.
15	143	28.0	42.0	7.5	21.5	0.51	0.22	0.34	0.68	0.18	II	Basic enclave in granite (rich in biotite).

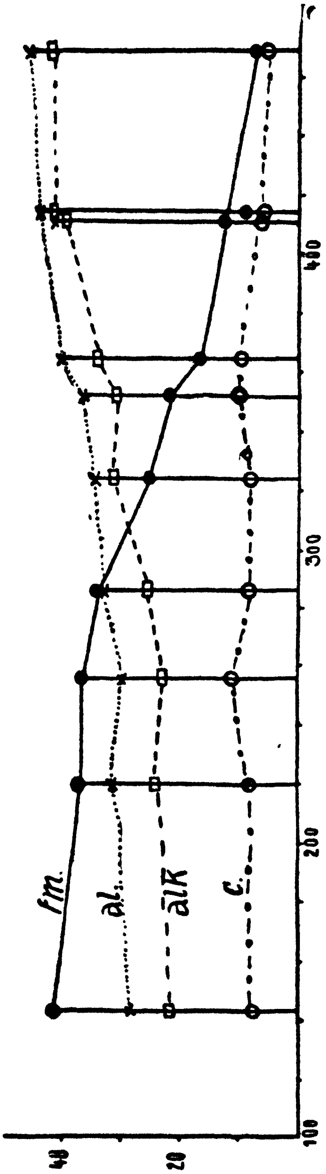


Fig: 20.

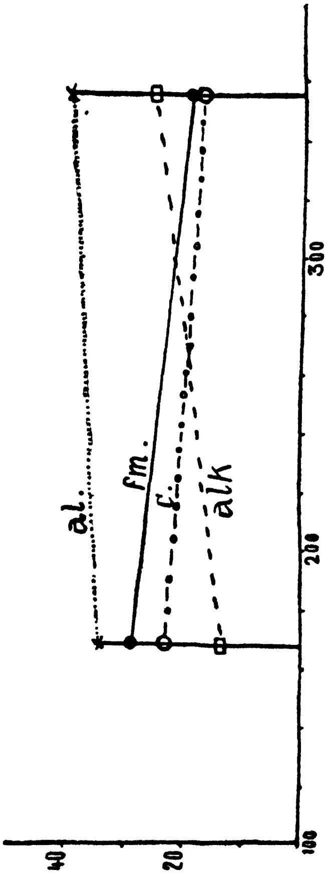


Fig: 21.

Differentiation diagram according to Niggli of the enclaves and country rocks of Striegau, Silesia.

Enclave-Differentiation in Striegau Area.

The molecular values (according to Niggli) of the rocks of the Striegau area are collected on Table 6. Two graphs, Figs. 20 and 21, have been constructed out of these molecular values.

One of the graphs, Fig. 20, possesses the following characteristics :

With the decrease of the molecular values of *si*,

fm rises abruptly as soon as it nears the enclave (*si* 352) ;

c remains fairly constant ;

al and *alk* decrease regularly.

This is all typical for lamprophyric differentiation (*loc. cit.*). The difference between (*al-alk*) is small. Therefore most of the aluminium oxide is used up to form alkali felspars, and the rocks in this group are certainly rich in *orthoclase.*

The following characteristics are observed in the other figure (Fig. 21)

With the decrease of *si* :

fm does not attain a high value, nor does it increase abruptly.

c has a fairly high value and gradually rises.

al and *alk* decrease.

The difference (*al-alk*) is here fairly high. The excess of *al* must combine with *c*, *i.e.*, the rock will be rich in anorthite molecules (*plagioclase*).

The rocks (Nos. 9 and 12, Table 6) having *si* values 277 and 208 show compositions which occupy intermediate positions between the fundamental tendencies given in the Figs. 20 and 21. In one case (*si*=277) *fm* is a little lower and *alk* a little higher than in the chief tendency of differentiation. In the other case (*si* 208), we find relatively high values of *fm* and *c*.

The above lamprophyric differentiation tendency[1] of the enclaves of Striegau and their mineral composition—one group rich in plagioclase and the other rich in orthoclase—agree well with the mineral composition, and lamprophyric structure and differentiation-tendency shown by the enclaves of Tiefenstein.

This is, I think, a widespread phenomenon. A lamprophyric differentiation tendency can probably be constructed with the enclaves of every region. This corresponds with the idea given by Beger,[1] according to whom " die basische Randfacies und die Schlieren sind in chemischer Hinsicht den Lamprophyren analog."

It has been said above that the enclaves occupy a position in the differentiation diagram (*see* Figs. 16, 17, 19) nearer to the granite than the lamprophyre. In support of our theory we may further add, in Beger's words, that, "in chemischer Hinsicht die basischen Rand-gesteine und *die Schlieren* sehr wohl lamprophyrischen Charakter tragen, dass sie aber im allgemeinen nur den sauersten Magmenstufen entsprechen, die bei der Lamprophyr differentiation entstanden sind. . . . In ihren mineralogischen und structurellen Eigenschaften ähneln die lamprophyrischen Randfazies *und die Schlieren*. . . . doch nur ausnahmsweise; die physikalischen Bedingüngen, unter denen ihre Kristallisation erfolgte, sind offenbar nur wenig verschieden gewesen von denen, die die Erstarrung der Tiefengesteine beherscht haben, mit welche sie in Verbindung stehen." [2]

[1] See Niggli. Lit. 44 (*a*) p. 132.

[2] See lit. 39, pp. 452–468. [Italics mine, AUTHOR.]

TABLE 7.—*The Enclaves and Country Rocks, Brocken, Harz Mountains.*

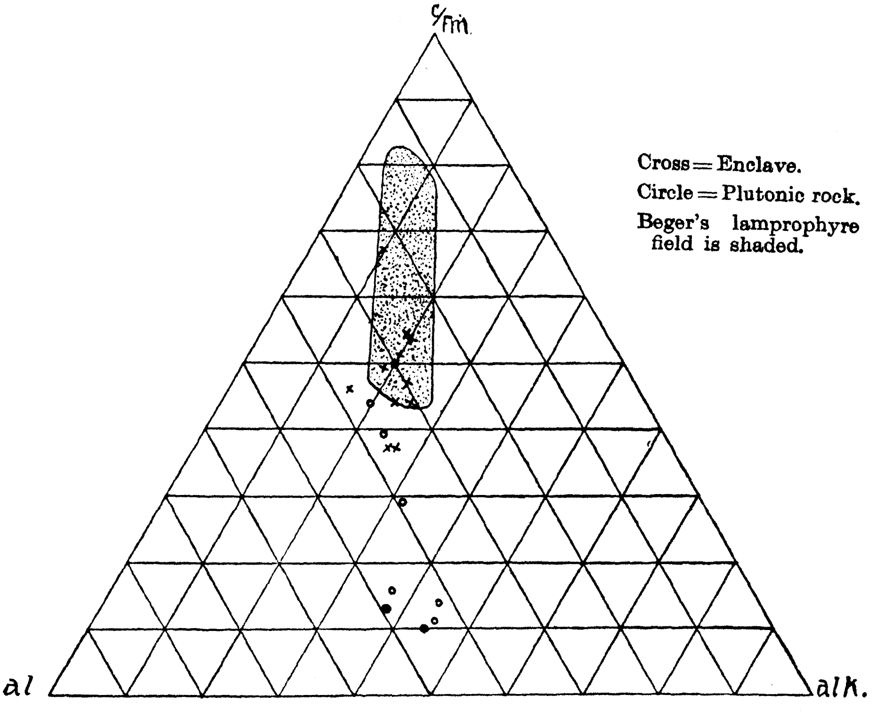
	si	al	fm	c	alk	k	mg	ti	p	c/fm	Section	
1	531	56.5	23	2	18.5	0.89	0.03	—	—	0.09	I	Border of granite.
2	497	49	9.5	3.5	38	0.82	0.17	—	—	0.37	III	Granite.
3	444	45	10.5	6.0	38.5	0.56	0.14	0.36	0.36	0.57	IV	Granite porphyry.
4	395	43	13.5	7.00	36.5	0.55	0.14	—	0.33	0.52	IV	Granite.
5	389	42	18.5	6.0	33.5	0.51	0.12	—	0.30	0.32	III	Granite porphyry.
6	373	42.5	15.5	8.5	33.5	0.52	0.18	1.56	0.31	0.55	IV	Granite.
7	368	39.5	20.5	8.5	31.5	0.48	0.15	1.86	0.31	0.41	III	Granite.
8	344	40.5	18.5	9.5	31.5	0.52	0.24	—	0.29	0.51	IV	Enclave in granite.
9	328	40.5	19.5	11.0	29.0	0.52	0.23	—	0.29	0.55	IV	Granite.
10	327	37.5	28.0	11.0	25.5	0.38	0.28	1.92	0.28	0.42	III	Enclave in granite.
11	276	36.5	30.5	8.9	24.5	0.45	0.29	1.02	0.76	0.28	III	Granite.
12	274	36.5	27.5	9.5	26.5	0.54	0.32	0.75	0.5	0.35	III	Enclave.
13	254	29.5	43.0	9.0	18.5	0.47	0.2	3.5	0.47	0.21	II	Granite.
14	250	30.5	36.5	13.0	20.0	0.43	0.22	3.1	0.70	0.35	III	Do.
15	215	33.5	32	12.5	22.0	0.43	0.21	—	0.6	0.39	III	Do.
16	211	31.0	37.5	16.0	15.5	0.27	0.36	1.0	0.2	0.43	IV	Qz. Diorite (Enclave)
17	208	28.0	45.0	15.5	11.5	0.26	0.31	4.7	1.2	0.36	III	Do.
18	190	31.0	37.0	21	11.0	0.39	0.45	1.9	0.6	0.57	IV	Do.
19	140	27.0	42.5	21.5	9.0	0.38	0.24	4.1	0.7	0.5	IV	Mica augite diorite.
20	121	21.0	51	22.0	6.0	0.15	0.46	2.6	0.4	0.43	IV	Gabbro.
21	112	24.5	39.5	30.0	6.0	0.24	0.69	0.7	—	0.76	V	Augite Norite.
22	108	20.5	56.0	19.5	4.0	0.23	0.75	0.6	—	0.35	III	Mica Norite.
23	102	23	42.5	31.5	3.0	0.31	0.79	—	—	0.74	V	Norite.
24	96.5	16.5	65.0	14.5	4.0	0.16	0.33	0.6	—	0.22	II	Olivine Gabbro.
25	91.5	16.0	61.5	18.0	4.5	0.22	0.74	1.5	0.2	0.29	III	Do.
26	90.0	20.5	53.0	23.0	3.5	0.27	0.75	0.6	—	0.43	IV	Do.
27	78.0	17.5	49.5	26.5	6.5	0.64	0.39	2.2	0.2	0.53	IV	Enclave in granite.

TABLE 7 (*a*).—*Enclaves and Country Rocks.*

	si	al	fm	c	alk	k	mg	ti	p	c/fm	Section.	
1.—	TYROL.											
1	259	38.5	24.0	20.0	17.5	0.47	0.40	—	0.26	0.86	V	Tonalite, Reisenferner, Tyrol.
2	230	35.0	31.5	19.5	14.0	0.4	0.29	—	0.4	0.62	IV	Granodiorite.
3	204	32.5	34.5	19.5	13 5	0.48	0.4	—	0.4	0.56	IV	Tonalite.
4	187	33.5	33.0	20.5	13.0	0.49	0.42	0.4	—	0.62	IV	Tonalite porphyry.
5	138	23.0	51.0	16.0	10.0	0.56	0.46	—	1.7	0.31	III	Enclave in diorite
2.—	ESSEX COUNTY, MASSACHUSETTS											
1	504	45.5	7.5	2.5	44.5	0.46	—	1.17	—	0.33	III	Granite. Free of mg.
2	488	44	8.0	3.0	45.0	0.32	0.1	—	—	0.35	III	Aplite.
3	469	43	13.0	1.0	43.0	0.45	—	—	—	0.07	I	Paisanite (?) free of mg.
4	465	46.5	5.00	1.00	47.5	0.41	—	—	—	0.2	II	Aplite dyke, free of mg.
5	298	39.7	22.0	2.3	36.0	0.48	0.01	—	—	0.10	I	Quartz syenitic enclave.
3.—	MT. ASCUTNEY, VERMONT.											
1	196	31	31	13	25	0.28	0.46	2.8	0.6	0.42	III/IV	Akerite, enclave in granite.
2	174	30	32	16.5	21.5	0.28	0.30	2.8	0.56	0.51	IV	Monzonite, enclave in Paisanite.
3	173	29.5	30.5	16.0	24.0	0.31	0.41	3.0	0.3	0.52	IV	Monzonite, enclave in Paisanite.
4	166	30.5	32	18.0	19.5	0.2	0.38	3.6	0.9	0.56	IV	Diorite.
5	163	26	39	15	20.0	0.2	0.52	2.4	0.7	0.38	III	Akerite, enclave in granite.
4.—	LAU ALAS, SUMATRA.											
1	456	51	2.5	6.0	40.5	0.48	0.71	0.72	0.36	2.4	VIII	Border of an enclave in granite.
2	438	47.5	9.0	5.5	38.0	0.52	0.4	0.35	0.35	0.61	IV	Granite.
3	238	32	36.5	12.5	19.0	0.35	0.44	0.8	0.40	0.36	III	Enclave in granite.
5.—	TSCHIGIRIN, KIEW, RUSSIA.											
1	430	46	11	7	36.	0.48	0.38	—	—	0.64	IV/V	Granite.
2	253	31	56	4	9.	0.41	0.16	—	—	0.07	I	Enclave in granite.

The results obtained above by the examination of a series of molecular values may further be tested by a review of the values shown by the term $\frac{c}{fm}$, which, as has been proved by experience, is a highly characteristic expression for certain features of the chemical nature of igneous rocks.[1]

It has been shown by Beger[2] that the lamprophyric-part-magmas of hypabyssal differentiation show chemical characteristics, which, on the whole, vary within narrow limits only. We may now also inquire whether the chemical composition of the enclaves, taken as a whole, compared with that of the chief acid and intermediate rocks associated with them, indicate a similar constant correlation. For this purpose further molecular values of the enclaves and the corresponding plutonic rocks have been collected in Table 7. The results in tables 6, 7 (a) and 8 have also been used.



Section III of Niggli's Concentration tetrahedron.

Fig. 22.

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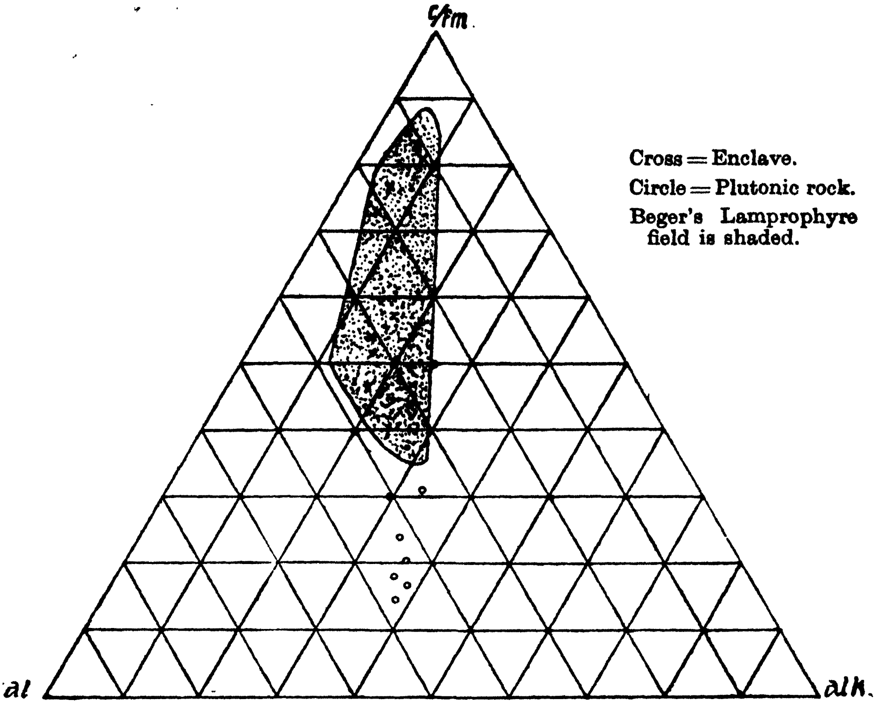
[1] See lit. 39.

[2] See lit. 39.



Section IV of Niggli's Concentration tetrahedron.

Fig. 23.

Figs. 22 and 23 show the projection of such molecular values as fall in Sections III and IV of Niggli's concentration tetrahedron. The X (crosses) indicate values belonging to the enclaves, the O (circles) those of the associated plutonic rocks. The diagrams also contain the lamprophyric field in these sections according to Beger. They are indicated by the shaded areas.

We see that the position of the enclave projections is to a very marked degree restricted to the lamprophyre fields. On the whole, however, we see a certain crowding of the points in the lower parts of the fields, which is evidently an expression of the fact that the chemical composition of the enclaves approaches that of the associated principal plutonic rocks more closely than do the lamprophyres. The enclaves represent a stage in the differentiation, which is intermediate between that of the plutonic rocks and the lamprophyres.

The $\frac{c}{fm}$ values of the enclaves are rather high. This is a characteristic of the lamprophyre.

TABLE 8.—*Molecular Values of Enclaves.*

si	al	fm	c	alk	k	mg	ti	p	c/fm	Section	Name, locality, etc.
414	44	9	5.5	41.5	0.4	0.26	0.0	1.0	0.61	IV	Core of an enclave in granite, Striegau, Silesia.
352	37	22	10.0	31.0	0.49	0.45	0.6	1.2	0.45	IV	Aplitic enclave, Riesengebirge, Silesia.
344	40.5	18.5	9.5	31.5	0.52	0.24	—	0.29	0.51	IV	Enclave in granite, Brocken, Harz.
327	37.5	26.0	11.0	25.5	0.38	0.28	1.92	0.28	0.42	IV	Enclave in granite, Brocken, Harz.
313	38.5	20.5	8.0	33.0	0.46	0.25	0.55	0.55	0.39	III	Border of an enclave in granite, Striegau, Silesia.
298	39.3	20.0	2.7	36.0	0.48	0.01	—	—	0.1	I	Quartz syenite enclave, Essex County.
274	36.5	37.5	9.5	26.5	0.54	0.32	0.75	0.5	0.35	III	Enclave in granite, Brocken, Harz.
261	39.0	24.0	18.0	19.0	0.77	0.38	—	—	0.75	V	Enclave in granite, Bernina, Switzerland.
259	26	43.3	11.2	19.5	0.8	0.58	3.0	1.4	0.27	III	Orthoclase-biotite apatite enclave in granite, Tiefenstein.
256	30.0	36.0	2.0	23.0	0.22	0.11	0.7	0.7	0.31	III	Enclave in granite (rich in biotite and plagioclase), Striegau.
253	46.0	11.0	7.0	36.0	0.48	0.38	—	0.2	0.64	IV	Enclave in granite, Tschigirin, Kiew, Russia.
240	36.0	25.0	19.0	20.0	0.4	0.42	4.0	0.6	0.76	V	Plagioclase-biotite magnetite enclave in granite, Tiefenstein.
238	32.0	36.0	12.5	19.0	0.35	0.44	0.8	0.4	0.36	III	Enclave in granite, Las Alas, Sumatra.
228	28.0	35.5	10.5	16.0	0.56	0.7	0.0	0.0	0.28	III	Enclave in granite, Riesengebirge, Silesia.
225	36.5	40.0	12.5	27.0	0.33	0.42	2.4	—	0.52	IV	Dioritic syenite enclave, Castle Mts., Montana.
211	31.0	37.5	16.0	15.5	0.27	0.36	1.0	0.2	0.43	IV	Quartz diorite enclave in granite, Brocken, Harz.
208	33.0	31.0	13.0	23.0	0.32	0.39	1.8	0.82	0.42	III/IV	Border of enclave in granite, Striegau, Silesia.
196	31.0	31.0	13.0	25.0	0.28	0.66	2.8	0.60	0.42	III/IV	Enclave in granite, Mt. Ascutney, Vermont.
195	34.0	39.0	7.0	20.0	0.67	0.41	—	—	0.18	II	
174	30.0	32.0	16.5	21.5	0.28	0.3	2.8	0.56	0.51	IV	Monzonitic segregation in Nordmarkite, Mt. Ascutney, Vermont.
173	28.5	30.5	16.0	24.0	0.31	0.41	3.0	0.30	0.52	IV	Monzonitic segregation in Paisanite, Mt. Ascutney, Vermont.
169	28.0	39.0	12.0	20.0	0.28	0.38	1.8	0.72	0.31	III	Enclave in granite, Riesengebirge, Silesia.
163	26.0	39.0	15.0	20.0	0.20	0.52	2.4	0.70	0.38	III	Segregation in granite, Mt. Ascutney, Vermont.
158	35.5	30.5	15.5	18.5	0.28	0.46	2.2	—	0.51	IV	Enclave in granite, Tempio Pusania, Sardinia.
143	28.0	42.0	7.5	21.5	0.51	0.22	0.34	0.68	0.18	II	Enclave in granite, Striegau, Silesia.
138	23.0	51.0	16.0	10.0	0.56	0.46	—	—	0.31	III	Enclave in diorite, Tyrol.
121	21.0	51.0	22.0	6.0	0.15	0.46	2.0	0.4	0.43	IV	Enclave in granite, Brocken, Harz.
119	11.0	56.0	24.5	8.5	0.24	0.44	2.7	—	0.44	IV	Enclave in granite, Zampechn, Bohemia.
78.0	17.5	49.5	26.5	6.5	0.64	0.39	0.22	0.2	0.53	IV	Enclave in granite, Brocken, Harz.
74	10.5	59.0	24.5	6.0	0.32	0.39	0.4	—	0.42	III/IV	Enclave in granite, Wehratal.

In Table 8 the molecular values (accd. to Niggli) of all the enclaves homœogènes of the areas that we have considered in the last few pages have been collected together. In Figs. 24 a, d, c, b. the graphs of the *al*, *fm*, *c*, and *alk* values of all these rocks have been plotted separately as functions of *si*.

We naturally cannot expect a uniform differentiation, as we are dealing here with the differentiates of different mother magmas.

The diagrams distinctly show, however, that for the whole series of enclaves, the different molecular groups vary within closely defined limits according to the *si* values. The graph in each case has the appearance of a narrow stripe outside of which practically no points are found to lie. The general tendency of the stripes may be resumed as follows :—

With the decrease of the values of *si* :—

The stripes of *al* and *alk* approach the abscissa.

The stripe representing the values of *c* rises but has a relatively low position.

The *fm* stripe rises abruptly and has a relatively high value.

The lines passing through the middle of the stripes correspond to the mean values of the molecular group with varying values of *si*. (Fig 24.) These mean values are given in Table 9, with a variation of 20 - 20 units in the *si* values, and have been used to construct the differentiation diagram (Fig. 26). Both molecular values and the diagram may be taken to represent the conditions obtaining in *idealised enclaves* of granitic, dioritic and syenitic rocks.

TABLE 9.—*The Ideal Enclaves.*

si	al	fm	c	alk	si′	c/fm	Section.	Magma type.
80	10	60.5	27.5	2.0	—	0.45	IV	Hornblenditic
100	16	54.0	24.0	6.0	—	0.44	IV	Do.
120	21	48.0	20.0	11.0	—	0.42	III	Lampro-Somaitic.
140	25	43.0	16.5	15.5	—	0.38	III	Lampro-Syenitic.
160	27.5	39.5	14.5	18.5	—	0.37	III	Do.
180	30.5	35.5	13.0	21.0	—	0.37	III	Do.
200	32.5	33	11.5	23.0	—	0.35	III	Syenite-Granitic.
220	34	31	11.0	24.0	—	0.35	III	Do.
240	35	29.5	10.5	25.0	—	0.36	III	Do.
260	36	28	10.0	26.0	—	0.36	III	Do.
280	37	26.5	9.5	27.0	—	0.36	III	Do.
300	37.5	25.5	9.0	28.0	—	0.35	III	Do.
320	38	24	8.5	29.0	—	0.35	III	Grano-Syenitic.
340	40	22	8.0	30.0	—	0.36	III	Do.
360	42	18.5	7.5	32.0	—	0.41	III	Do., Si too high.
380	43	16.5	7.5	33.0	—	0.45	IV	Rapakiwitic.
400	44.5	14.0	7.0	34.5	—	0.50	IV	Do.
420	47.5	9	6.0	37.0	—	0.67	IV	Do.

Graphs of al, fm, c and alk values of the enclaves as functions of si.

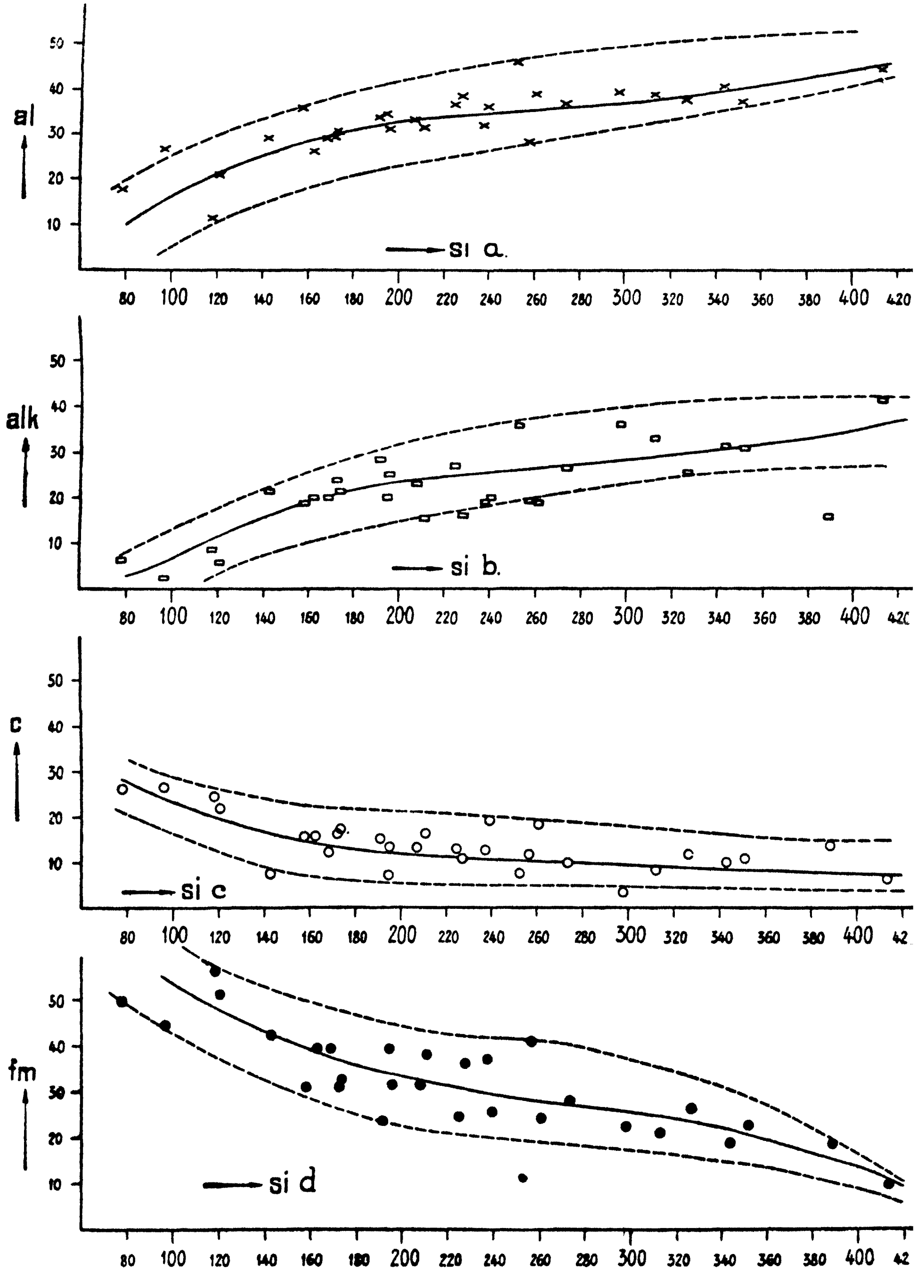


Fig. 24

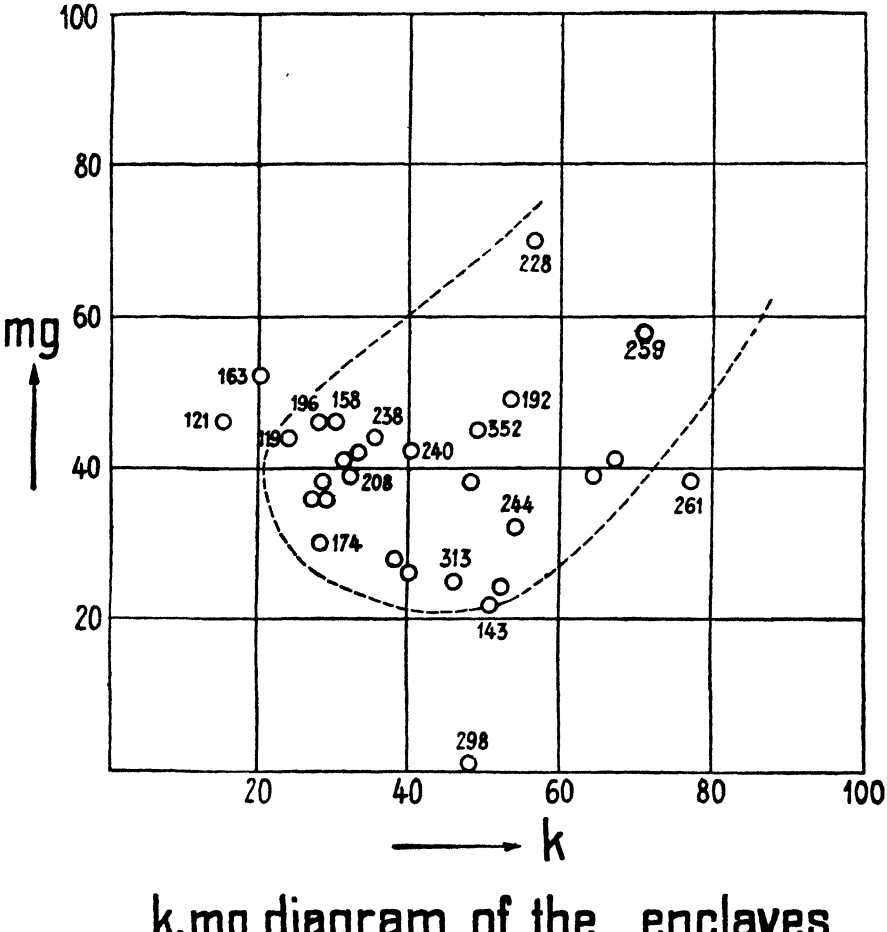

100
80
60
40
20
mg
20
40
60
80
100
k
228
259
163
196
158
192
121
119
238
352
240
208
244
261
174
313
143
298
k,mg diagram of the enclaves

Fig. 25.

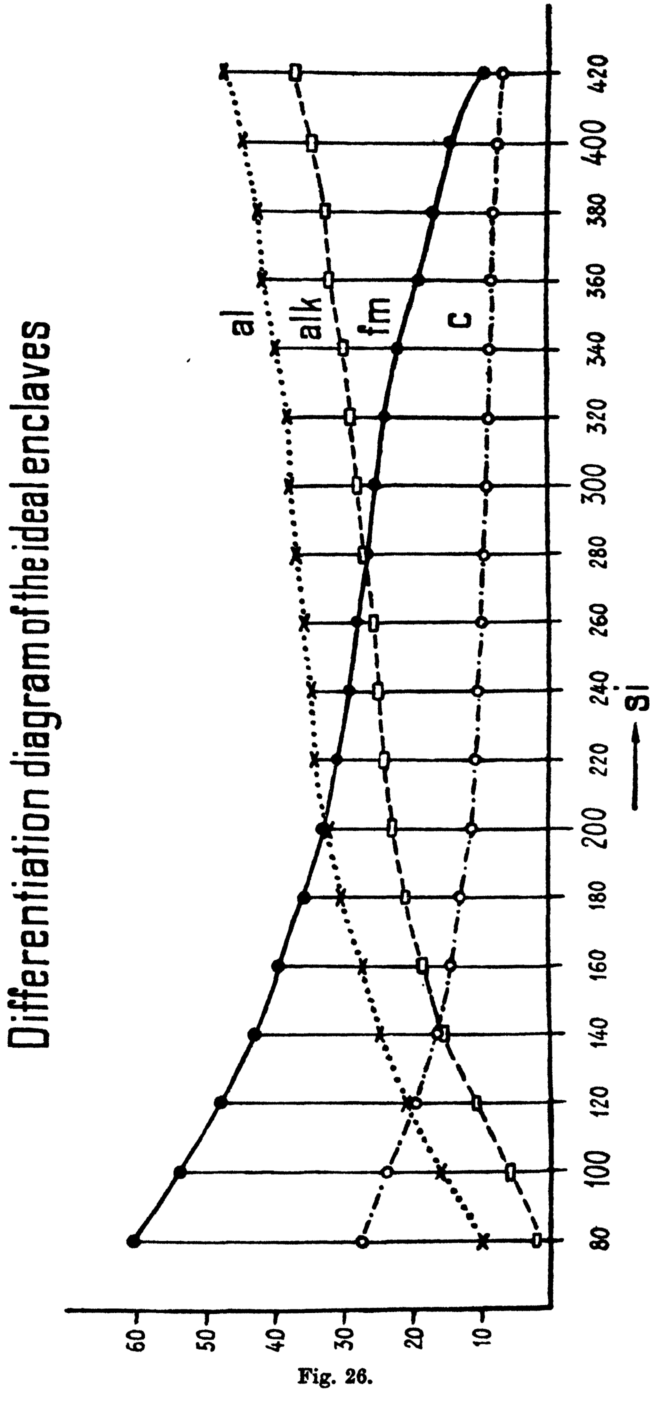

Differentiation diagram of the ideal enclaves
al
alk
fm
c
si
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
10
20
30
40
50
60

Fig. 26.

It will be seen that the composition of such theoretical, or as one may say, " Ideal " enclaves, is in every case syenitic while the differentiation as a whole is closely analogous to that of the potassic clan. The diagram is characterised by the following points :—

The isofalic ($al=fm$) point lies at *si* 200 which is characteristic for both calcalkalic and potassic clans. The value of *c* in the isofalic region is, however, smaller than that of *alk*, which at once characterises the diagram as belonging to the potassic clan. (At the isofalic point of the calcalkali clan $c = 22$ and $alk = 12$.)

With decreasing *si*, *al* and also *alk* sink. The difference (*al-alk*) however remains almost constant.

The difference between *fm* and *c* is rather small towards the higher values of *si*, and regularly increases with sinking *si*. At $si = 400$, $(fm\text{-}c) = 3$, and at $si = 80$, $(fm\text{-}c) = 33$.

The *k*, *mg*, diagram of the enclaves (Fig. 25) possesses a close similarity with that of the potassic clan.

The differentiation diagram of the enclaves and country rocks of the Striegau area (Fig. 20) also possesses characteristics of the potassic clan having :—

(*a*) *alk* greater than *c* at the isofalic point, and

(*b*) a small and almost constant value of (*al-alk*) throughout the system.

The diagram (Fig. 20) further possesses a remarkable similarity with the differentiation diagram of the " Ideal Enclaves " (Fig 26), the general nature of the curves of *al*, *fm*, *c* and *alk* being in both diagrams almost the same.

The curves obtained from the molecular values of the idealised enclaves can, therefore, be said to have more than only theoretical importance. In the differentiation diagram of the enclaves of the Striegau area we have an example of its practical worth.

VI. THE DYKES.

In the chapter on the geology of Tiefenstein it has been said that subsequent to the consolidation of the granite, dyke rocks of various sorts intruded into the main mass of the granite as well as into the gneisses. The strike of these dykes has, generally speaking, a N.W.–S.E. direction. In some cases the strike direction is at right angles to the above.

The natural cleavage planes of the granite are also directed N.W.–S.E. and N.E.–S.W. On this account it may be supposed that the dykes intruded into the already existing cleavage planes of the granite. That the granite was already relatively cold is evident from the fact that most of the dykes show a sharp boundary against the granite, and that they are much finer grained at the edges than at the centre.

These dykes can be divided petrographically into the following three groups.

- A. Acid.
  - (1) Aplite granites, *e.g.*, Schlossberg granite.
  - (2) Aplites.
- B. Intermediate.
  - (3) Granite porphyry.
    - (a) Coarse grained, *e.g.*, Niedermühle Type.
    - (b) Fine grained, general Type.
- C. Basic.
  - (4) Lamprophyres.

A. Acid Dykes.

I. *Dykes of aplite granite.* (*Schlossberg granite.*)

(1) At Schlossberg, Tiefenstein. Strike almost E.W., dip. 65° S.

(2) South of the Hauptsteinbruch, Tiefenstein.

II. *Aplite Dykes.*

(1) Aplite sill at the S.E. corner of Humbert's house, Tiefenstein.

(2) In the gneiss by the Albtal road, opposite the Wirtshaus, Tiefenstein.

(3) In the gneisses by the Schachen-Niederwihl road, just at the entrance to the forests.

(4) Two dykes of schistose aplite, in the gneisses W. of Schachen.

(5) A sill of schistose aplite, falling to the south, in the gneisses at the junction of the Richenbach and the Alb.

(6) Aplite sill in the gneisses at the top of the first tunnel, N. entrance.

(7) About 200 metres N. of Hohenfels, by the Albtal road, aplite dyke in gneisses. Strike N.E. 30°.

About half a dozen dykes are observed between the last-mentioned (No. 7) and the Wirtshaus at Hohenfels.

(8) About 30 metres from the fifth tunnel in gneiss. Strike W.N.W. 280°, dip. 80° S.W. Breadth 2 metres.

At the same place as 8, but higher up, there are a number of aplite sills in the gneisses.

(9) About 40 metres S. of the fourth tunnel in the quarry of aplite. It is cut through by a lamprophyre dyke.

(10) About 6 metres S. of the lamprophyre dyke, No. 16.

(11) In the granite by the Ibach road about 150 metres from the Albtal strasse.

1.—THE SCHLOSSBERG GRANITE.

Aplite granite[1] or fine grained dyke granite has been observed to occur in the form of stocks at two places within the Albtal granite, in my observation area. They have attained a thickness of about 30 metres, much greater than that usually reached by the other aplite dykes of the locality. The more important of the two occurrences is near the Albtal road, about 50 metres N. of the amphibolite outcrop, Tiefenstein, where a government quarry in the rock was (on my recommendation) recently started. Here it is about 26 metres broad and it can be traced from among the forests near Tanne to the eastern side of the Schlossberg. At the latter hill it does not pass through the crest where the castle once stood, but can be seen just under the ruins of the castle walls. It possesses a sharp boundary against the granite.

The other occurrence of the rock is in the valley of the Alb, just to the south of the Hauptsteinbruch, Tiefenstein. Here it is about 30 metres in breadth and extends along the western slopes of the Alb, from the street to the heights of Niederwihl.

In the hand specimen it is a middle grained greyish-white rock consisting of quartz, felspar (partly decomposed) and biotite. The composition is therefore that of a normal granite from which it is distinguishable by its finer grain. On the other hand, it is of a coarser grained structure than the ordinary aplites. For these reasons it has been thought best to distinguish it by the term

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[1] Philipp.—Lit 48, pp. 16–17, reports the occurrence of similar aplitic granite, within the granites of Wiesental in connection with "Die Jüngeren Granite," and specifies it as Type Mambach.

" Schlossberg Granite." One interesting feature common to both the occurrences are the black tourmaline suns and nodules with reaction rims around them (described in connection with the Enclaves Pneumatogènes, Chapter V, p. 68).

Most of the cleavage planes of the rock occurring between Tanne and Schlossberg are covered with crystals of barytes while druses of fluorite and barytes are of quite common occurrence in the rock.

The fine grained variety which is seen in the marginal portion of the dyke sometimes shows cataclastic structure.

Under the microscope the rock is found to consist of a hypidiomorphic granitic aggregate of quartz, felspar, biotite, muscovite and tourmaline. Apatite, sericite, chlorite and limonite are the common accessories.

The *quartz* is the most common and abundant mineral of the rock. It occurs in rounded grains or in big patches which, between the crossed Nicols, are seen to consist of several individuals. It never possesses a crystalline outline. Inclusions of gas bubbles are common. They are arranged in lines roughly parallel to one another.

Felspars :—

The K-Felspar is nearly always perthitic. It is usually partly kaolinised and has often been changed into muscovite (Sericitised). Sometimes the perthitic orthoclase possesses a core of plagioclase. The cleavage lines parallel to (001) and (010) are well developed.

Typical Microcline with cross hatching is sometimes met with.

The Plagioclase is equally abundant as the perthite. It usually possesses polysynthetic twinning lamellæ, and is sometimes zoned. The individuals occur in prisms, their refractive index is lower than that of quartz and optically they are biaxial positive. The extinction angle on the section about vertical to $n_{\underline{\alpha}}$, against $(001) = +60°$. Its maximum extinction angle about the zone of $[010] = -10°$, and its extinction angle on $(001) = +1\frac{1}{2}°$. By these characters the plagioclase is determined as oligoclase-albite (about Ab_{13} An_{87}).

Muscovite (Sericite) of both primary (pneumatolytic) and secondary origin is found in the rock. The perthites are found to be traversed by a system of irregular veins having the appearance of a net work. Sometimes individual veins may widen out at places and here occur plates of muscovite with good cleavage lines and crystallographic edges. The veins are never found to enter into quartz and only rarely into plagioclase.

From the above may be distinguished the muscovites of secondary origin produced by the alteration of the biotites and tourmaline. At many places, both these minerals have been bleached, with accompanying formation of limonite.

Biotite occurs sometimes in aggregates, but usually in disseminated patches. It is of the common brown lepidomelane variety. Usually it is decomposed partly or fully into muscovite, chlorite and limonite.

Tourmaline is the other coloured constituent of the rock. It is usually brown, but green and blue varieties also occur. (Other properties similar to those mentioned on p. 68.)

Apatite and magnetite are the rare accessories.

The following is the result of a chemical analysis of the rock. Pieces free from tourmaline and biotite suns were selected and powdered for the purpose of analysis :—

Schlossberg Granite.

Analysed by S. K. Ray.

	Weight per cent.	Molecular proportions.
SiO_2	73.50	1,225
TiO_2	Trace	—
P_2O_5	0.07	1
Al_2O_3	15.08	148
Fe_2O_3	0.11	1
FeO	0.43	6
MnO	0.02	—
MgO	0.06	1.5
CaO	0.89	16
Na_2O	3.13	50
K_2O	6.10	65
$+H_2O$	0.81	—
$-H_2O$	0.08	—
Total	100.28	

Molecular proportions according to Niggli.	
si	425
al	51.5
fm	3.0
c	5.5
alk	40.0
k	0.56
mg	0.16
ti	—
p	—
$\frac{c}{fm}$	1.73
si′	+ 185

Position in the magmatic field : Section VII.

Specific gravity 2.57

Magma type .. .. .. Aplite-granitic.

Norm of the rock.

Mineral	Weight per cent.
Apatite	0.33
Orthoclase	36.14
Albite	26.20
Anorthite	3.61
Corundum*	2.4
Magnetite	0.23
Hypersthene	0.81
Quartz	30.40

* Due to decomposition of the rock.

2.—Aplites.

Whereas the rocks of the Schlossberg granite type occur in fairly big dykes and possess a middle grained structure and grayish white colour, the aplites on the other hand, occur in smaller dykes, only a few metres in breadth and possess a fine-grained structure and flesh-red colour. Further the Schlossberg granite has a uniform structure, while phenocrysts of felspar and quartz are often met with in the aplite. The aplite dykes can, as a rule, not be traced for more than a few metres.

The general microscopical characters of the rocks may be stated as follows :—

They usually consist of a hypidiomorphic aggregate of quartz, sericitised orthoclase, microcline, plagioclase and biotite, the latter changed into pennine and leucoxene and occasionally into muscovite and limonite.

The chilled marginal portions of the aplitic dykes in granite usually show a very fine grained micropegmatitic aggregate of quartz and felspar. At one place in the gneisses (S. of the 2nd tunnel) the margin of an aplite dyke is found to possess a typical rhyolitic structure, and under the microscope a directive texture is visible, in which the phenocrysts of tourmaline and corroded felspar are arranged with their long axes in subparallel arrangement following the direction of the stream line of the glassy ground mass.

The particular specimen analysed by me possessed the following characteristics. It was collected from the dyke in the granite opposite the saw-mill Tiefenstein.

Megascopically it is similar to the other aplite rocks. Its microscopical characters are as follows :—

It consists of quartz, felspars, and mica, and possesses a hypidiomorphic granitic structure.

The *quartz* possesses innumerable gas bubbles sometimes arranged in a rectangular pattern. It shows a straight margin against the plagioclase, while there are many instances of resorption at the contact between orthoclase and quartz Apatite is a common inclusion in quartz. Plagioclase is also sometimes found enclosed within a big quartz individual.

Most of the *felspars* are more or less decomposed. Orthoclase is commonest of all. It has usually become perthitic by the separation of veins of albite.

The *plagioclase* (near albite) is polysynthetically twinned.

The *biotite* is usually decomposed into chlorite (*pennine*) and leucoxene. Sometimes it has been bleached into muscovite.

Apatite occurs in needles and forms the commonest accessory mineral of the rock.

The following is the result of the chemical analysis .—

Aplite.

Analysed by S. K. Ray.

	Weight per cent.	Molecular proportions.
SiO_2	73.18	1,219
TiO_2	—	—
P_2O_5	0.31	2
Al_2O_3	15.70	154
Fe_2O_3	1.08	7
FeO	0.02	—
MnO	0.04	—
MgO	0.06	1.5
CaO	1.34	24
Na_2O	2.62	42
K_2O	5.31	56
$+H_2O$	0.75	—
$-H_2O$	0.07	—
Total	100.48	

Molecular proportions according to Niggli.	
si	419
al	53.0
fm	5.0
c	8.5
alk	33.5
k	0.57
mg	0.01
ti	—
p	0.6
$\frac{c}{fm}$	1.7
si′	+ 184

Position in the magmatic field Section VII.

Specific gravity 2.64

Magma type .. .. Aplite granitic

Norm of the rock.

Mineral	Weight per cent.
Apatite	0.67
Orthoclase	27.13
Albite	22.00
Anorthite	4.73
Corundum	3.98
Hæmatite	1.12
Enstatite	0.15
Quartz	34.40
(Water	0.82)
Total	100.00

B. Intermediate Dykes.

3. THE GRANITE PORPHYRY.

(a) *Coarse-Grained Niedermühle Type.*

The granite porphyry in the locality can be divided into two distinct types. One of them is lilac grey granülar, consisting of white phenocrysts of felspar (sometimes as big as 60 mm. × 20 mm.) and quartz (approximate size 8 mm. × 4 mm.) and biotite (3 mm. × 3 mm.) embedded in a light coloured groundmass of quartz and felspar.

The other type is quite glassy. It possesses an almost brick-red colour and consists of small brick-red phenocrysts of felspars (4 mm. × 2½ mm.) and quartz (occasionally 4 mm. × 3 mm.) embedded in a semi-glassy groundmass.

The coarsely porphyritic type is referred to as "The Niedermühle granite porphyry." It has a very wide expanse, greatly exceeding that of the other variety. For this reason I have noted it separately on the map, where it can be traced from opposite the saw-mills at Ibach, right across the heights of Wilfingen and the valley of the Alb to the sandstone outcrop at Stieg. The small occurrences of granite porphyry in the Buntsandstein north of Unteralpen possess identical megascopical and microscopical characters as the rock of Niedermühle itself. I am convinced that these various occurrences form portions of the same dyke. The small occurrence of the granite porphyry in the small quarry in the granite, about 200 metres south of the last house Unteralpen, is also texturally and structurally identical with the Niedermühle granite porphyry. It is an apophysis of the latter.

The general strike direction of the big dyke is N.W.-S.E. Its mean breadth is about 250 metres, and its total length within my observation field, from S. of Oberalpen to Ibach, is about 5 kilometres.

Dykes of Niedermühle granite porphyry seem to be very persistent in their character everywhere in the Southern Black Forest. Phillip reports the occurrence of a big granite porphyry dyke of similar petrographical characters from Wiesental, and believes it to have intruded into the crevice formed by the old carboniferous trough fault. In connection with this granite porphyry he writes[1] "In seinem petrographischen Habitus und in seinem geologischen Auftreten unterscheidet sich deutlich der grosse, ca 50 m. mächtige Gang, der sich fast 10 km. weit verfolgen liess und von Altensteiner Kreuz die Karte durchziet bis zum Kasteler Wirtshaus und über die Kartengrenze hinaus bis oberhalb Wembach. Vermutlich streicht er über den Karbongraben hinweg. Das Streichen ist ca 50°–60° N.W. Im Süden dürfte der Gang mit einem der granitporphyre des Wehratales zusammenhängen."

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[1] See lit. 48.

" Das Gestein unterscheidet sich sofort von den übrigen Granitporphyren durch seine, bis 5 cm Durchmesser zeigenden Orthoklaseinsprenglinge."

Erdmannsdörffer[1] also reports such granite porphyry dykes, which sometimes attain a thickness of about 100 m. and can be traced as far as 4 km., from Wehratal. The strike direction is 40° N.W.

Under the microscope the rock is found usually to show a typical porphyrytic structure possessing phenocrysts of felspar, quartz and occasionally of biotite embedded in a eutectic (granophyric) groundmass of quartz and felspar. The biotite phenocrysts when present usually possess well-shaped outlines. The felspars also usually occur with well-marked crystalline outline, but the *quartz* always shows a reaction rim and signs of corrosion in the margins. In some instances portions of the groundmass are found within the phenocrysts of water-clear quartz. Gas bubbles are common inclusions in quartz.

In certain cases reaction rims and signs of corrosion may also be observed around the phenocrysts of felspar. In both the cases (quartz and felspar) these reaction rims consist of microlitic aggregates of quartz and felspar, much smaller than those found in the groundmass, arranged radially along the whole margin.

The biotites are the pleochroic green type which is common in the granite porphyry rocks.[2] Usually they are changed into green pleochroic pennine, or sometimes they are decomposed into limonite and leucoxene. These changes are probably due to high contents of aqueous vapour in the magma.

The pleochroic colours vary between

$$n\gamma \quad = \quad n\beta \quad > \quad n\alpha$$

Olive green. Light green to colourless.

On account of such pleochroic colours some of the individuals resemble hornblende, but the extinction parallel to the cleavage lines and the interference colours prevent confusion.

The coarse-grained granite porphyry rock occurring to the east of the hill at Albert possesses quite fresh, *brown biotite.* Its pleochroic colours are

$$n\gamma \quad = \quad n\beta \quad > \quad n\alpha$$

Dark brown. Light brown to colourless.

Erdmannsdörffer. See lit. 15.

[2] See lit. 15.

The *felspar phenocrysts* occur usually in water-clear crystals. Individuals partly decomposed and thereby becoming cloudy also occur.

Among the *monoclinic felspars* there are seen both the water clear sanidine-like felspar and perthitic orthoclase.

Microcline with cross hatching is quite common among the phenocrysts.

The *porphyritic plagioclase* crystals are found to be characterised by the properties of albite.

All the felspars have separated *limonite.*

The properties of the phenocrysts of quartz have been stated above.

As regard the accessories, the nature of the occurrence of *chlorite* has been referred to in connection with the occurrence of biotite and that of *limonite* in connection with biotite and felspar. *Apatite* occurs in needles as well as ingrains; *muscovite* is a pneumatolytic product. It is found associated both with the groundmass and the phenocrysts of orthoclase.

Before leaving this chapter on the Niedermühle granite porphyry it should be made clear that the structure of the rock in the main outcrop Ibach—Wilfingen—Niedermühle varies greatly from place to place. It is quite natural that in such a big mass different parts were subjected to different conditions of cooling and crystallisation ; for this reason portions possessing almost granitic structure may be found within this typical hypabyssal rock.

Thus, at Ibach, for instance, half-way between the river bed and the heights of Wilfingen, a grey rock occurs within the granite porphyry which, in the hand specimen, appears rather porphyritic, but under the microscope shows a typical hypidiomorphic granitic structure, and consists of brown biotite (with chlorite and leucoxene) quartz, orthoclase and albite.

(b) *The Fine-Grained Granite Porphyry.*

Not only megascopically, but also microscopically, this type differs considerably from the coarse-grained type. The structure is holocrystalline porphyritic, with phenocrysts of felspars, quartz and biotite, of which the felspars and quartz often show a micropegmatitic intergrowth resembling a poicilitic structure.

The biotites are green and pleochroic. Their pleochroic colours vary between

$n\gamma$	$=$	$n\beta$	$>$	$n\alpha$
	Bluish green.			Green to colourless.

In many cases they have been decomposed into chlorite separating limonite, sagenite and leucoxene. Muscovite is also sometimes formed by the alteration of biotite. The pleochroic colours of the biotites closely approach those of hornblende. Brown biotites, partly decomposed (chloritised) also sometimes occur.

The felspars are mostly orthoclase, twinned according to the Carlsbad law. Plagioclase is not very common. Where present it is so decomposed or so finely intermingled with quartz as to render accurate determination impossible. Microcline with cross hatching is sometimes observed.

Quartz.—The phenocrysts of this mineral are very rare.

Apatite, rutile (usually as needles in biotite), *chlorite, limonite, sericite* and *magnetite* are the common accessory minerals.

The particular example of the rock analysed was collected from the dyke crossed by a lamprophyre dyke about 2,000 m. north of Tiefenstein. Its structure and mineralogical composition are identical with those of the other occurrences of the fine grained type, and its chemical analysis gave the following result :—

GRANITE PORPHYRY.

Analysed by Dr. J. Jakob, Ph.D., Priv. Doz., Eidg. Tech. Hochschule, Zurich.

	Weight per cent.	Molecular proportions.
SiO_2	67.06	1,117
TiO_2	1.29	16
P_2O_5	0.32	3
Al_2O_3	14.36	140
Fe_2O_3	2.98	19
FeO	2.39	33
MnO	0.08	1
MgO	1.51	1
CaO	0.77	38
Na_2O	3.61	58
K_2O	3.85	40
$+H_2O$	1.93	—
$-H_2O$	0.13	—
Total	100.28	

Molecular proportions according to Niggli.	
si	308
al	39
fm	30
c	4
alk	27
k	0.42
mg	0.35
ti	4.4
p	0.8
$\frac{c}{fm}$	0.13
si′	+ 100.00

Section I.

Specific gravity .. .. 2.64.

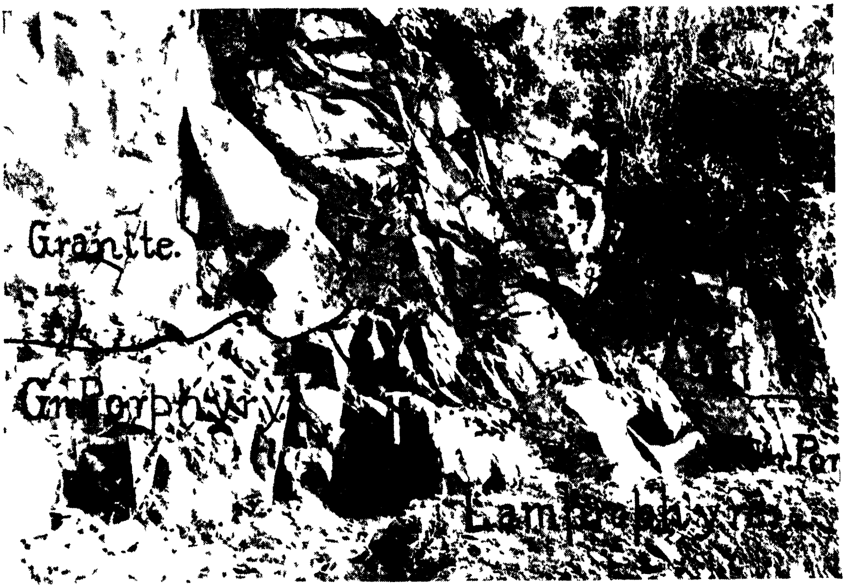

Fig 27

Granite porphyry dyke cut through by a younger Lamprophyre dyke
(See pp 14, 97).

Norm of the granite porphyry.

Mineral.	Weight per cent.
Apatite	1.1
Rutile	1.3
Orthoclase ..	22.2
Albite	30.8
Anorthite	1.1
Corundum	3.9
Magnetite	4.4
Hypersthene ..	5.8
Quartz	28.1
(Water	2.06)
Total ..	100.76

The excess of Al_2O_3 is probably due to the decomposition of biotite which has lost a portion of its K during chloritisation.

The c-value of the rock is too low. The rock seems to have also lost Ca during decomposition.

C. Basic Dykes.

THE LAMPROPHYRES.

It is a well-known fact that the granite porphyries in the Black Forest are younger than the aplites. The age of the Lamprophyres, however, remained undetermined as not a single instance of intersection of dykes of these latter rocks with the first mentioned has hitherto been met with.

Such an intersection was, however, found by the author on the occasion of an excursion with Dr. H. Suter. The locality is situated by the Albtal road about 2,000 m. North of Tiefenstein, and here (as the accompanying photograph shows) may be distinctly seen that the granite porphyry is cut by a younger lamprophyre dyke. The conclusion is therefore justified that the lamprophyres are the youngest dyke rocks of the Black Forest. (Fig. 27).

The following is a list of the lamprophyre dykes observed by the author :—

(1) In the N.E. margin of the Government quarry in the granulite, Albbruck. Strike N.W.-S.E. Dip vertical. Breadth about 2 metres.

(2) In the N.W. margin of the granulite laccolith, Albbruck, in the bed of the Alb. Strike about N.S. vertical. Breadth 7 metres.

(3) In the S.W. margin of the granulite laccolith, Albbruck, in the bed of the Alb. About 150 metres N.E. of the railway viaduct. Breadth about 2 metres. Strike 70° S.W.

(4) Near the pipe-lines of the hydroelectric power works belonging to the paper factory of Albbruck, about 1,200 metres N.W. of the granulite outcrop. This seems to be a continuation of the dyke occurring in the N.E. margin of the granulite quarry, Albbruck. (No. 1.)

(5) On the eastern bank of the Alb, about 600 metres south of Hohenfels.

(6) About 90 metres south of the 5th tunnel, Albtal road, in gneiss. Strike W.S.W. 250°. Dip, about vertical. Breadth 170 cm.

(7) About 210 metres south of the 4th tunnel, Albtal road, in gneiss. Strike E.W. 275°.

(8) About 6 metres north of No. 7, in the gneisses by the Albtal road. About a metre in breadth.

(9) About 50 metres N. of No. 8. In the gneisses by the Albtal road. About a metre in thickness.

(10) About 20 metres north of No. 9, in the gneisses of the Albtal road. Strike N.E. 55°. Dip 65° S.E.

(11) About 100 metres south of the 4th tunnel, Albtal road, in gneiss. Strike W.N.W. 280°. Dip, vertical.

(12) About 40 metres south of the 4th tunnel, Albtal road, in the gneiss. This lamprophyre dyke crosses an aplite gneiss intrusion. Strike N.W. 300°. Dip, vertical. Breadth 2 metres.

(13) About 50 metres south of the 2nd tunnel, Albtal road, in gneiss. Strike N.W. 325°. Dip, vertical. About 2 metres broad.

(14, 15, 16, 17) Four dykes, two with apophyses in the 2nd tunnel, Albtal road. The one just at the northern entrance of the tunnel strikes N.W. 315°, its dip is 70° S.W., and it is a metre in breadth. Two others strike N.E. and the fourth one strikes about N.S. Their breadth varies between 8 metres and 2 metres. Almost the whole of the 2nd tunnel consists of lamprophyre rock.

(18) About 100 metres north of the 1st tunnel, Albtal road, near Tiefenstein, in gneiss. Strike N.N.W. 285°. Dip about 90°. Breadth about 1·75 metres.

(19) By the footpath, Tiefenstein-Etzwiel, about 60 metres above Tiefenstein, in the granite, W. of Riedekar.

(20) By the Albtal road, in granite, about 600 metres south of the amphibolite outcrop, Tiefenstein. Strike N.N.W. 340°; vertical. Breadth about 40 cm.

(21) Adjacent to Humbert's house, Tiefenstein, in amphibolite. Strike W.N.W. 295°. Dip about vertical.

(22, 23) Two dykes close to one another, one with an apophyse. By the Albtal road, about 100 metres south of the saw-mills, Tiefenstein. Strike N.W. 305°. Dip 67° S.W.

(24) In the granite, S. of the Hauptsteinbruch, Tiefenstein. Strike N.W. Breadth about a metre.

(25, 26, 27, 28) Four lamprophyre dykes are found penetrating the granite at the S.W. corner of the Silk Spinning and Weaving Mills, Tiefenstein. One of them is dislocated by a fault. The granite in the neighbourhood of these dykes has also a rather schistose appearance. This indicates that certain differential movements have taken place in the granite subsequent to the dyke intrusions. The analysis of the lamprophyre rock published in this paper was done with a specimen obtained from the most southerly of these 4 dykes. This latter shows typical weathering into rounded balls. The breadth of the dykes varies between 90 to 20 cm. The general strike direction is N.N.W. 290°, and the dip is about 90°.

(29, 30, 31, 32) Three lamprophyre dykes are found in the granite near the end of the hydroelectric power canal (opposite the sluice gate) belonging to the Weaving and Spinning Mills, Tiefenstein. Their thickness varies between three metres and one metre; the general strike direction is about N.W. 300°. Dip 70° S.W.

(33) Dyke within the granite, S. of the Hauptsteinbruch, Tiefenstein, breadth about 2 metres. Strike N.W.

(34) In the granite near Köpfli, about 800 metres N. of the anorthosite outcrop, Tiefenstein.

(35) In the granite by the Albtal road, cutting a granite porphyry dyke, about 2 km. N. of the anorthosite outcrop, Tiefenstein. Breadth 3 metres. Strike N. 274° E. Dip 50° S. (Fig. 27.)

(36) In the granite about 30 metres S. of the amphibolite-outcrop, Niedermühle, by the Albtal road.

(37) In the gneisses at Hauenstein, W. of Hauenstein-Hochsaal Road, just at the junction of the latter with the "Landstrasse," opposite the Rhine.

(38) On the eastern slopes of the Mühlebach, in the forests about 100 metres N.W. of the machine shop, Hauenstein.

(39, 40) Two dykes in the southern outcrop of the injection gneisses, Dogern, in the bed of the Schurlebach.

(41, 42) Two dykes in the bed of the Hölzlibach, near the southern margin of the lower granulite outcrop.

(43) One big dyke about 25 metres N. of the point where the Volkenbach bifurcates. It is about 25 metres broad and strikes N.W. across the rivulet.

(44) Another dyke about 80 metres N. of the last.

(45) A little outcrop, N. of the mill, Birndorf, on the eastern slopes of the valley.

(46, 47) Two dykes in the forests, about 225 metres N.E. of the workshop, Kiesenbach, breadth each about 2 metres. Strike N.W.

Petrographically speaking, the rocks found at the above occurrences are practically identical to one another. A general description will therefore suffice for all the cases.

The lamprophyre rocks found in my observation area may be described as middle to fine-grained compact rocks, possessing conchoidal fracture and colours varying between greyish black to reddish black.

I have found them to be the toughest of all the rocks in the area, which makes the preparation of suitable hand-specimens difficult.

The structure of the rocks vary with the position in the dyke, it being generally found that the centres are coarser grained than the margins. In the field, the lamprophyres, apart from the colour, may easily be distinguished by their peculiar angular appearance when fresh, and by their earthy (sometimes shaly) decomposition products on the face of the dykes, when weathered. Another common form of weathering is for the rock to separate into elliptical masses which are earthy outside but quite fresh in the centre. Some show effervescence with hydrochloric acid. The rock seems to have a great tendency to develop calcite (or dolomite) when decomposed.

Under the microscope the rocks are found to possess a hemicrystalline porphyritic structure, consisting of phenocrysts of biotite,

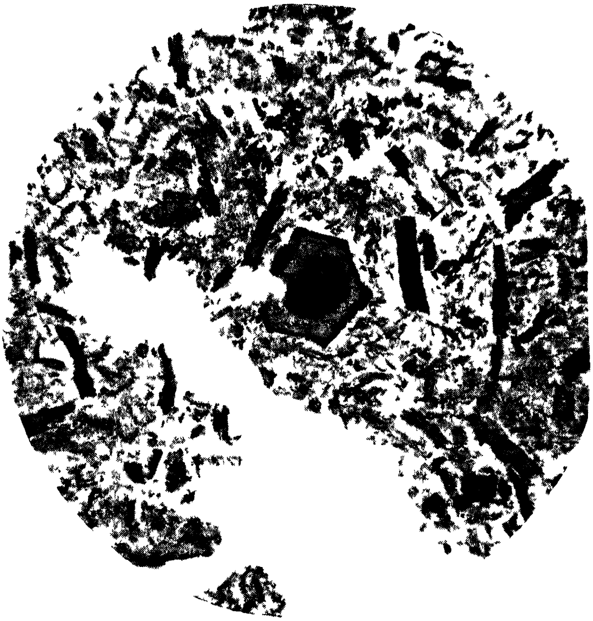

Fig. 28.

ZONED BIOTITE.

Magnification 24 × Plane polarized light augite, chlorite, cordierite (?) and sometimes quartz, felspar and calcite (or dolomite) embedded in a trachytic groundmass, consisting of biotite, chlorite, felspars, and sometimes glass. Magnetite, limonite and needles of apatite are very common accessories. In some of the examples the apatites attain an importance almost equal to that of the biotite in the groundmass. It is an interesting fact that the orthoclase-biotite-apatite enclaves mentioned on p. 61 have a structure similar to some of the lamprophyres, and are very rich in apatite. The biotites in the groundmass are arranged fluidally or in an irregular manner, or sometimes they, together with the apatite needles, give rise to a " bushel " structure, or again they are found to radiate from a central point.

The *biotites* are of the common brown pleochroic lepidomelane type. They occur in prisms as well as in non-pleochroic regular or lozenge-shaped six-sided cross sections, sometimes with signs of corrosion in the margins. Occasionally, as the result of corrosion, grains of magnetite have been separated in the marginal regions and gave rise to so-called " opacitic " rims.

In many instances the biotites are zoned. Individuals with a light-brown core and a deep-brown periphery are the commonest type. Specimens were also met with of the very rare type of zonal biotite, possessing a deep-brown core and a light-brown intermediate layer surrounded in the peripherial region by another deep-brown zone. (See Fig. 28.)

The opacite formation is explained as resorption accompanied by reaction, of the biotite phenocrysts by the melt. As a result, some of the Fe^{II} molecules have been oxydised into Fe^{III} and separated as magnetite. The zoning can probably also be explained by the varying degree of oxydation of the iron.

In many cases the biotites have been changed into patches of green or colourless chlorite which has retained the cross-section of the former. The chlorite has been further changed into calcite, quartz, limonite, actinolite, etc.

The *augite* phenocrysts occurring in the rock are of the (microscopically) colourless diopside variety. Prismatic and octagonal sections of the mineral are met with in good condition in many of the fresh rock specimens. The surrounding faces are prisms (110) and pinacoids (010).

Very often the diopsides have been decomposed into chlorite and calcite. Direct transition between the former and the two latter are in many occasions observed. In most of the cases the newly formed minerals, carbonate (calcite or dolomite) or chlorite, or a mixture of both have retained the octagonal, hexagonal or prismatic cross section of the original diopside. Fibrous serpentine and needles of actinolite, that are sometimes met with within the chlorite patches, are probably also direct decomposition products of diopside.

A microscopical feature of many of the lamprophyres in my area are lozenge shaped aggregates of chlorite, serpentine, actinolite, calcite and quartz, which neither answer the description of altered pyroxene, hornblende or biotite. Indeed, they may be found side by side with individuals of these minerals that are perfectly fresh or hardly decomposed. This points to the fact that the mineral from which chlorite is derived must be easily decomposable and more so than those mentioned above.

The key to the primary nature of these lozenges seems to be indicated in several instances, where at the centre of the chlorite aggregates are to be found the remains of a colourless mineral of birefringence similar to quartz (perhaps somewhat higher). Its optical nature is biaxial negative. These properties are in agreement with those of felspar or cordierite.

The presence of cordierite in lamprophyres has previously been mentioned from several localities. A good example is quoted by Rosenbusch.[1]

Chlorite occurs in aggregates of well-marked triangular, prismatic or hexagonal outline as well as in irregular patches. Diopside, biotite and cordierite, are found, as has been mentioned above to have changed into chlorite when decomposed. It is therefore evident that most of the chlorite aggregates present in the rock are derived from these minerals. Some of the chlorite aggregates, however, possess diamond shaped cross sections, so very characteristic for hornblende, that very probably at least, some of them are derived from this mineral though not a single amphibole crystal could be found. In some of the specimens the arrangement of the chlorite patches shows indications of flow structure.

The chlorites are usually light green and sometimes very slightly pleochroic (pennine), but colourless individuals also occur. They possess a refractive index higher than quartz, and a rough surface. The interference colours are low (deep grey of the first order, corresponding to $\gamma - \alpha =$ about 0.007), sometimes abnormal. Optical characters, biaxial and positive. In many instances the

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[1] Rosenbusch, Mikroskopische Physiographie, Stuttgart, 1907, Vol. II, p. 663 and Vol. I, (2) p. 164.

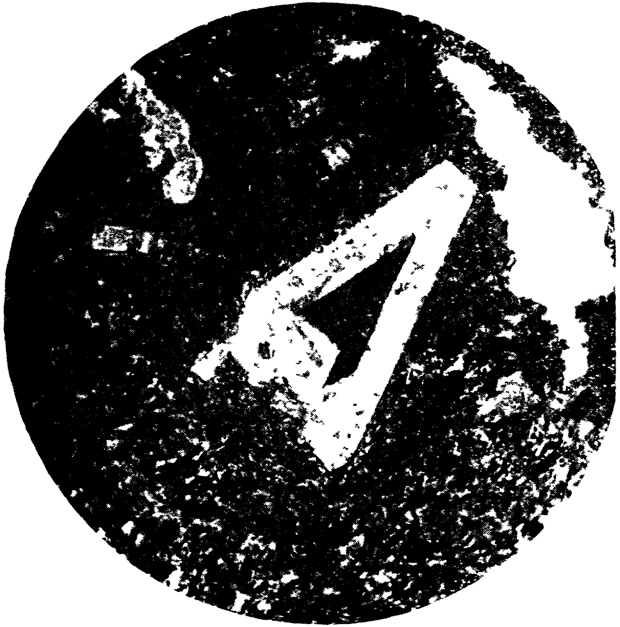

Fig. 30.

QUARTZ PSEUDOMORPH.
Magnification: 40 ×.
Plane polarized light.

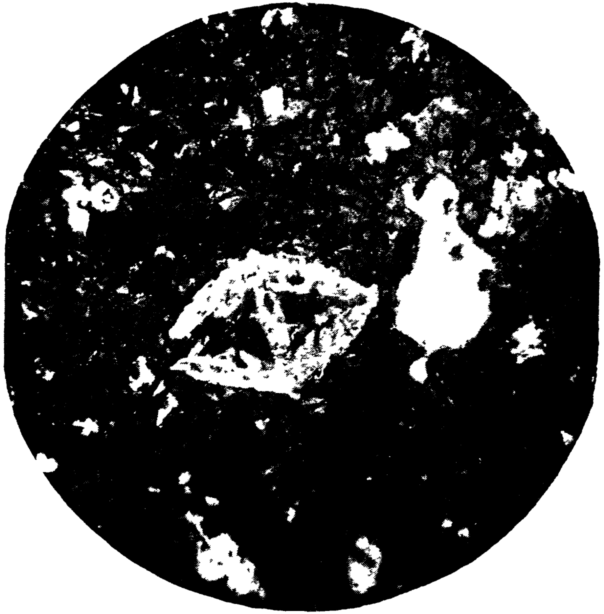

Fig. 29.

QUARTZ PSEUDOMORPH.
Magnification: 40 ×
Plane polarized light.

blades of pennine are associated with serpentine and actinolite. Other aggregates are found to consist of chlorite and quartz, or of chlorite, cordierite, sillimanite, calcite and grains of magnetite, and occasionally of green, slightly pleochroic diopside, mica, actinolite, etc.

Most of the aggregates of these minerals still show distinctly, the original crystalline outlines of the minerals from which they are derived.

Occasionally chlorite individuals are met with, which remain almost dark between the crossed nicols, and show biaxial negative character with very small axial angle ($2V =$ about 20°).

Calcite occurs in patches either irregular in shape or in aggregates possessing well-marked octagonal or crystalline outline closely associated with quartz. Sometimes it occurs in bundles radiating from a point. Some of the chlorite patches contain calcite (or dolomite) or are found to be penetrated by needles of calcite.

Quartz is quite a common accessory mineral of the rock. Usually it occurs in aggregates of several individuals, but single water-clear individuals (augen quartz) surrounded by a reaction rim consisting of minute blades of biotite and grains of magnetite are occasionally met with. It is interesting to note that the quartz is in many cases found to occur in association with chlorite and calcite in lozenge shaped aggregates. Enclosed within these are found regularly shaped cores consisting of groundmass. (See Figs. 29 and 30). Probably these shapes are pseudomorphs of quartz after a rhombic or monoclinic mineral. The quartz sometimes shows biaxial positive character.

Apatite is another plentiful accessory mineral, and it is an interesting fact that the Orthoclase-biotite-apatite enclaves mentioned on page 61 possess a lamprophyric structure and are also very rich in apatite.

Limonite.—Grains of this mineral are often found in chlorite side by side with magnetite.

Magnetite.—This mineral is occasionally found arranged along the margin of chlorite individuals. Sometimes the grains are found irregularly distributed all over the surface of the chlorite. They have apparently been separated during the decomposition of the mineral which gave rise to chlorite.

Pyrite also occurs as an accessory mineral.

The groundmass consists of a holocrystalline trachytic aggregate of biotite and felspar. The latter is sometimes found to be twinned according to the Carlsbad law. These individuals are very small and for this reason could not be more closely determined, but I think they are *orthoclase*. *Plagioclase* with the following characteristics was sometimes observed in the groundmass. It possesses low refractive index. $n\gamma$ is its first bisectrix. The extinction angle on a section about vertical to $n\gamma$ against the cleavage lines = − 4°. These facts speak for andesine or andesine-oligoclase $Ab_{68}\,An_{32}$.

The particular specimen analysed was collected from the dyke mentioned in the list on p. 99 as No. 25–28. It possesses the same megascopical characteristics as the other lamprophyre rocks of the area.

Under the microscope the rock is found to consist of phenocrysts of diopside and chlorite embedded in a coarse trachytic groundmass consisting of biotite and felspars. Quartz and actinolite, &c., are the accessories.

The augites are all colourless. They occur in prisms as well as in octagonal or hexagonal cross sections. The relief and interference colours are fairly high. The latter correspond to a value of $(n\gamma - n\alpha) = 0.02$ to 0.025. The optic axial angle (2V) is quite small. The extinction angle, measured on the pinacoid face = about 45°. In some cases it has been changed into chlorite and calcite and some of the aggregates of these minerals still show distinctly the original cross section of the augites.

Chlorite.—The big green lozenges or prismatic patches which are so characteristic of all the lamprophyres of the area occur here also. They correspond to the general description given above.

Typical water clear "*augen quartz*" with reaction rim consisting of minute blades of biotite and grains of magnetite are common. Some other individuals are found to be traversed by innumerable cracks. Quartz is also found to accompany most of the calcite sections.

Calcite occurs as irregular individuals or as aggregate with outlines derived from the diopside individuals. It is often accompanied by quartz.

Inclusions of *microcline* and *orthoclase* have been observed in the rock.

The felspars in the groundmass consist mostly of plagioclase. Some orthoclase also occurs in the groundmass. The rock may therefore be called an augite minette.

LAMPROPHYRE.

Analysed by :—Dr. J. Jakob, Ph.D.,
Priv. Doz. Eidg. Tech. Hochschule, Zurich.

	Weight per cent.	Molecular proportions.
SiO_2	52.64	877
TiO_2	1.82	23
P_2O_5	0.40	3
Al_2O_3	13.51	132
Fe_2O_3	2.22	14
FeO	6.75	93
MnO	0.25	3
MgO	8.21	205
CaO	6.02	107
Na_2O	1.42	25
K_2O	3.29	35
$+H_2O$	2.89	
$-H_2O$	0.18	
CO_2	0.62	
Total	100.22	

	Molecular proportions according to Niggli.
si	140
al	21.0
fm	52.5
c	17.0
alk	9.5
k	0.60
mg	0.62
ti	3.7
p	0.45
$\frac{c}{fm}$	0.32
si′	+2
Section	III

Specific gravity :—2.72.

Magma type :—Hornblenditic.

Norm of the rock :—

Mineral.	Weight per cent.
Apatite	1.0
Rutile	1.84
Orthoclase	19.46
Albite	12.05
Anorthite	20.57
Magnetite	3.25
Diopside	5.17
Hypersthene	28.83
Quartz	4.26
H_2O	3.07
CO_2	0.62
Total	100.12

The analysed lamprophyre is the most basic of all the lamprophyre rocks of the Southern Black Forest analysed until now. The molecular values of the lamprophyre rocks of the Southern Black Forest will be found on p. 70 of this paper.

COLLECTION OF NEW ANALYSES.

For ready reference the molecular values of the new analyses published in this paper are collected in Table 10.

A detailed consideration of the general differentiation phenomenon underlying the hercynian rocks of the Southern Black Forest can be only undertaken after the completion of the research work now being carried on in the surroundings of Laufenburg. A differentiation diagram of the aplite, granite and lamprophyre rocks of the Southern Black Forest has already been published by P. Niggli.[1] This shows a Pacific type of differentiation.

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[1] Niggli. Petrographische Provinzen der Schweiz, see lit. 43. See also lit. 44 (*a*), p. 133.

TABLE 10.—*Collection of New Analyses published in this Paper.*

	si	al	fm	c	alk	k	mg	ti	p	$\frac{c}{fm}$	si′	Magma Type	Name, Locality, etc.
A.—HERCYNIAN ROCKS AROUND TIEFENSTEIN.													
1	425	51.5	3.0	5.5	40.0	0.56	0.16	—	—	1.73	+185	Aplite granitic	Schlossberg granite, Tiefenstein.
2	419	53.0	5.0	8.5	33.5	0.57	0.01	—	0.6	1.7	+184	Do.	Aplite from near the Saw Mill, Tiefenstein.
3	308	39	30	4.0	27	0.42	0.35	4.4	0.8	0.13	+100	—	Granite porphyry (decomposed).
4	283	39	21	16	24	0.57	0.54	2.79	—	0.76	+ 87	Normal granitic.	Albtal granite.
5	259	26	44	6	24	0.66	0.58	3.0	1.4	0.14	+ 63	Lampro syenitic.	Orthoclase - apatite - biotite enclave in the Albtal granite.
6	240	36	25	19	20	0.40	0.42	4.0	—	0.76	+ 60	Granodioritic	Plagioclase - biotite - magnetite enclave in the Albtal granite.
7	140	21	52.5	17	9.5	0.60	0.62	3.7	0.45	0.32	+ 2	Hornblenditic	Lamprophyre.
B.—ROCKS OF THE GRUNDGEBIRGE.													
1	425	50	11	2	37	0.58	0.50	—	0.17	0.18	+177	Aplite granite	Granulite, Albbruck.
2	121	45.5	6.5	40	8	0.35	0.19	1.10	—	6.2	− 19	Labrador-felsitic —Anorthositic.	Hornblende-Anothosite, Tiefenstein.
3	112	24	43.5	23	9.5	0.32	0.53	0.40	0.40	0.52	− 26	Gabbrodioritic.	Amphibolite, Tiefenstein.
C.—MISCELLANEOUS.													
1	305	54	4	1	41	0.92	0.28	—	—	0.25	+ 41	—	Orthoclase phenocryst in the Albtal granite.

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Curriculum Vitæ.

I (Suhrid Kumar Ray) was born on the 1st January, 1895, at Kurulgachi, District Nadya, Bengal, India, as the youngest son of the late Mr. Sayaram Ray. I belong to the Nadya Raj family.

Between the years 1910 and 1911 I attended the school of the London Missionary Society's Institution, Bhawanipur, Calcutta, and in 1911 passed the Matriculation examination of the University of Calcutta, being placed in the First Division.

From 1911 to 1913 I studied at the Bangabashi College, Calcutta, and passed the Intermediate Science Examination of the Calcutta University in 1913, again being placed in the First Division.

From 1913 to 1916 I studied at the Presidency College, Bengal. My chief subjects were Geology (Honours' Course), Mathematics and Chemistry. My professors were Sir P. C. Ray, Drs. Mullick, Brown, Cotter, Jones and Mr. Das Gupta. In 1916 I passed the B.Sc. Degree Examination of the Calcutta University.

In 1918-19 I worked in the Forest Department, Bengal, under Sir H. A. Farrington, Bart., and Messrs. Glasson, Gibson and Choudhury.

I came to Europe in 1920. From 1921 to 1924 I worked at the Zürich University, taking the complete course of Mineralogical-Petrographical Studies, including Geology, Chemistry, Physical Chemistry, Palæontology and Geography.

In July, 1924, I entered for the Doctorate Examination after completing this thesis under the guidance of Prof. Niggli.

My professors in Zürich were Messrs. Niggli, Schardt, Grubenmann, Wehrli, Karrer, Henri, and Rollier.